The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIX No. 2 FEBRUARY, 1958

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in every industry

Top illustration shows a combined high and low pressure delivery type Mono-Radial Pump. Because of its compactness and suitability for self-contained hydraulic equipment, this type of Mono-Radial Pump was chosen by Messrs. R. Hoe & Crabtree Limited for their 750 Ton Hydraulic Matrix Moulding Press (also shown).

for efficiency fit a

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Mono-Radial Control Valves are arranged for one or more hydraulic supplies under manual, remote or power operation.

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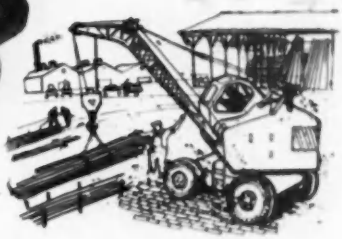

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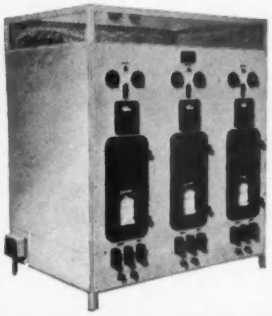
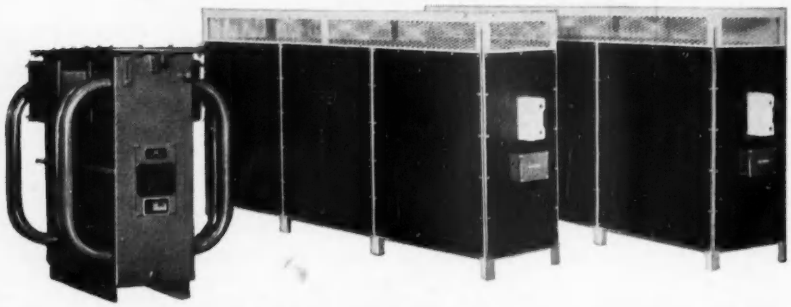


in rectifier equipment

you need G.E.C. reliability



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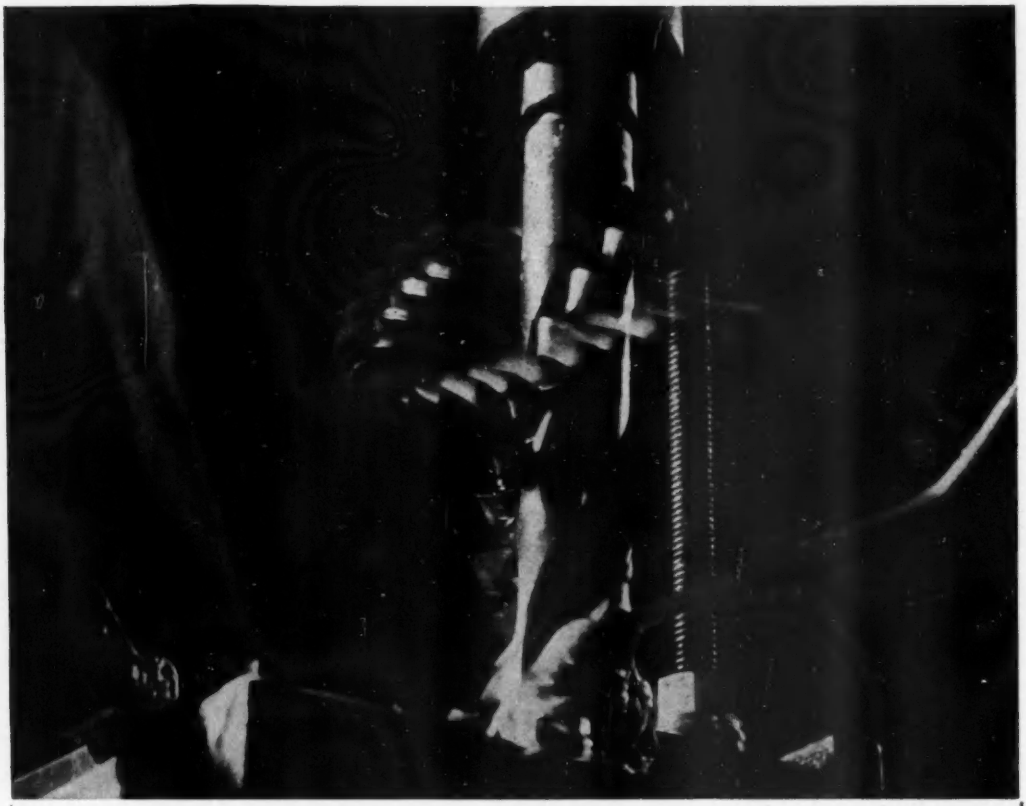

There is danger here—danger to sight and limbs. But safety can so simply take the place of that danger. "Armourplate" glass shields give certain protection. And because the operator can see what is happening he works more confidently and efficiently. Accident rates drop, and production rises when "Armourplate" glass shields are fitted.

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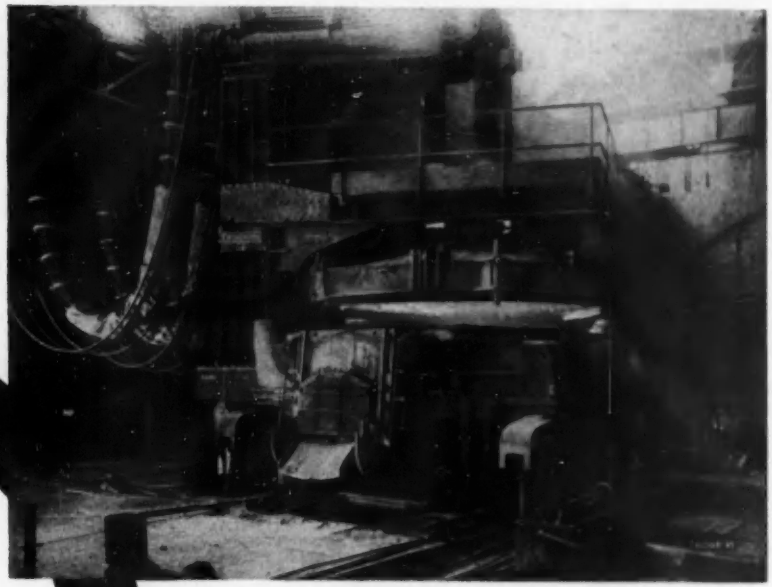

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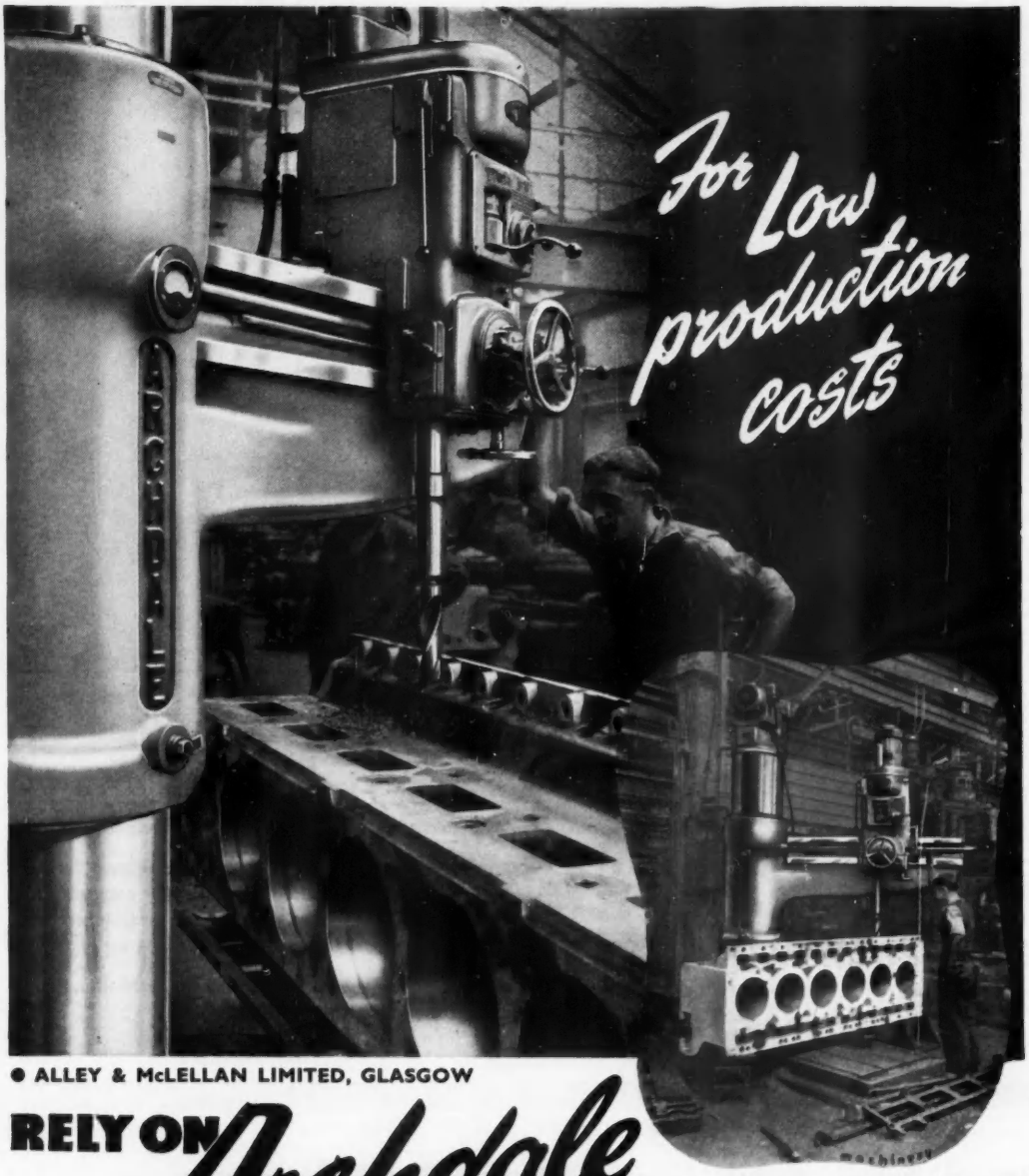

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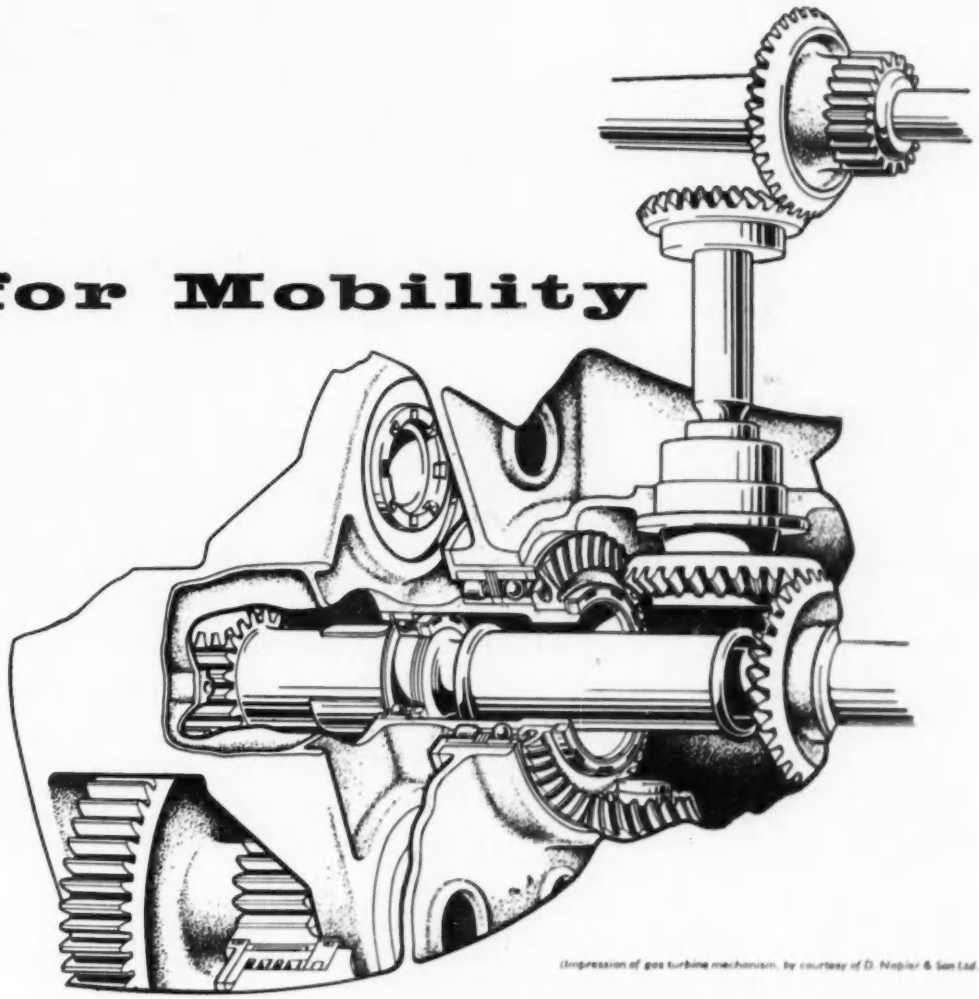


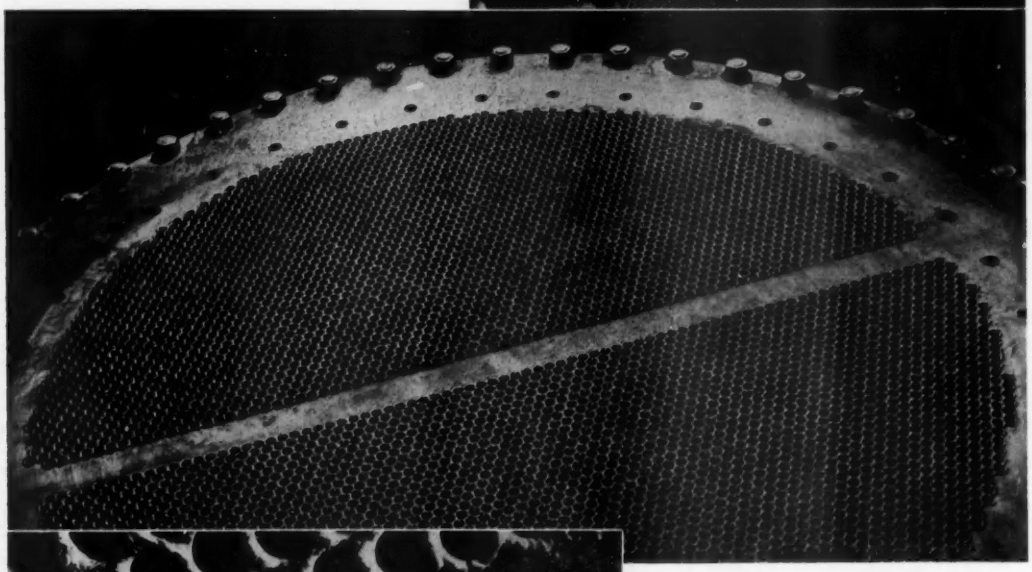
(Impression of gas turbine mechanism, by courtesy of D. Napier & Son Ltd.)

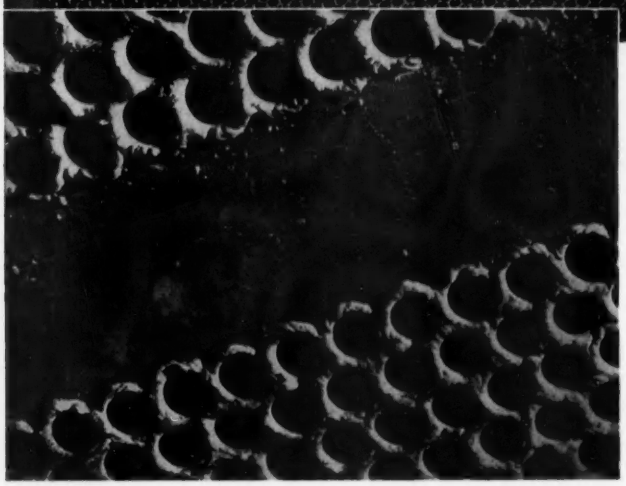
Buses, trams, cars and aircraft would literally grind to a stop were it not for frictionless movement of their metal parts. Just as important as lubrication are carefully heat treated bearing surfaces. Town gas of known declared calorific value is the most effective fuel for all heat treatment processes.

Issued by the Gas Council

FEBRUARY, 1958 Volume 19, No. 2

Dexterity in WELDING





Tube plate for a Heat Exchanger, incorporating 5,518 tubes $\frac{3}{4}$ in. dia., and involving 1,078 footage of welding.

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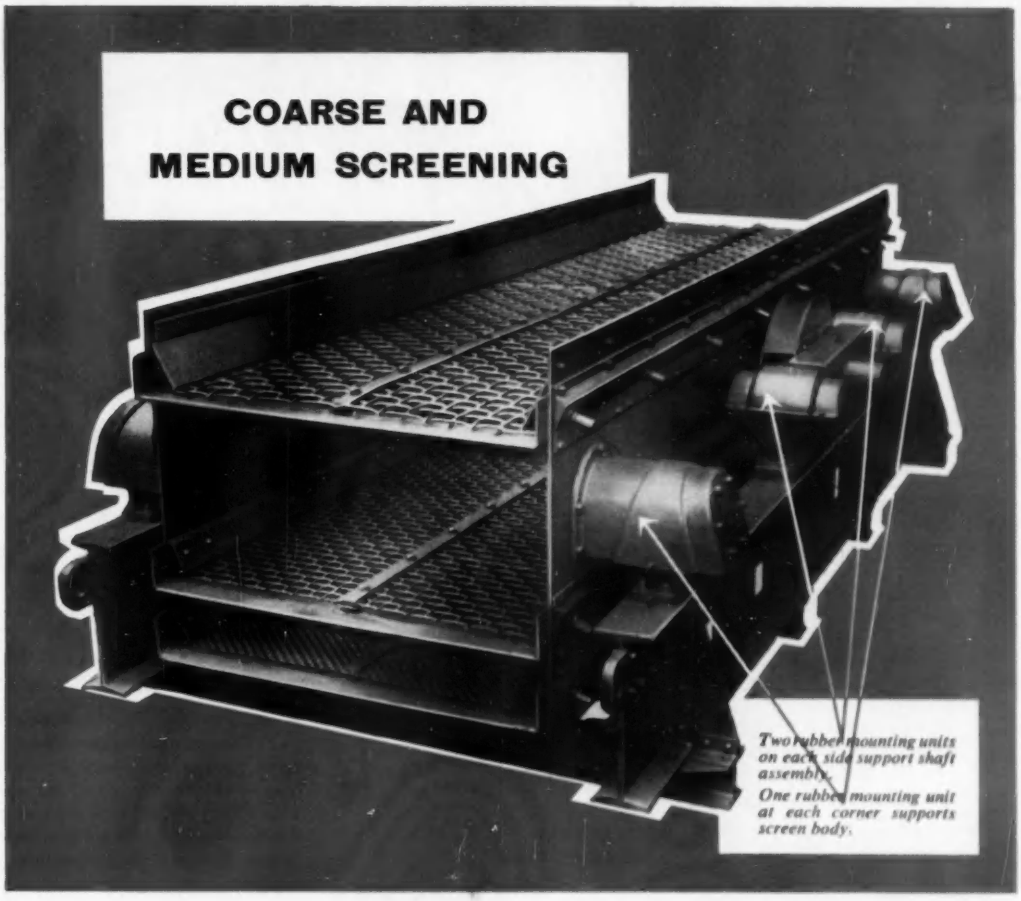
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Two rubber mounting units on each side support shaft assembly.
One rubber mounting unit at each corner supports screen body.

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High capacity coarse and medium screening for crushed rock, gravel and other materials with sizings up to 10 in. opening. Moving parts of the screen float entirely on rubber giving absolute freedom to develop maximum screening capacity. Massive rubber mountings support the shaft assembly, to absorb vibration completely. Ty-rock screens are available in many sizes with either single, double or triple screening surfaces.

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TGA 78

"But why can't they use my magnet?"

"Well, you see Johnny, it's because *your* sort of magnet can't be switched 'on and off'!"

"*Huh! I wouldn't like mine to do that!*"

"I know, but then you don't use yours to control water or gas and things."

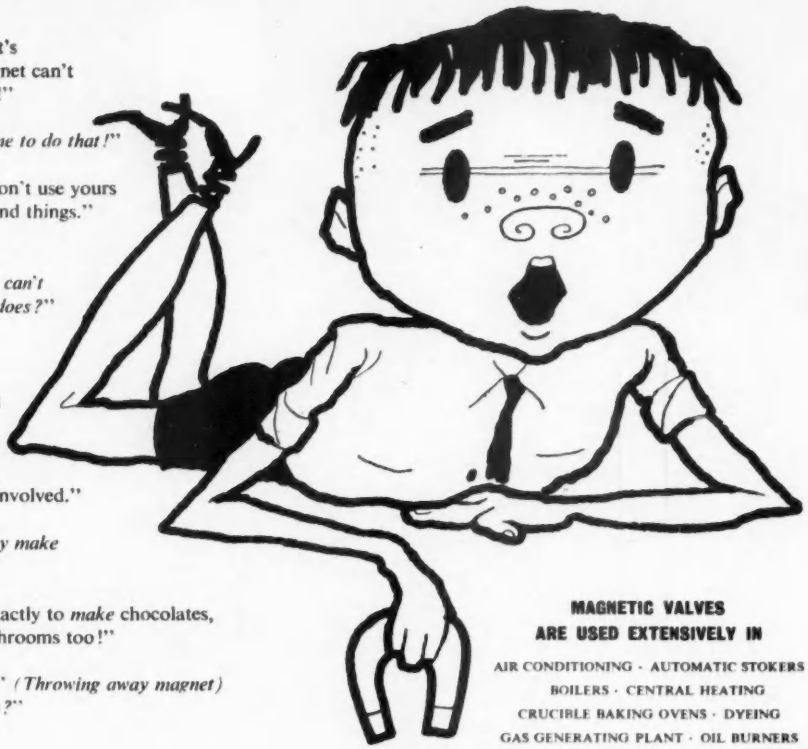
"*Control water or gas? Seems stupid to me—why can't they use a tap like Mum does?*"

"Ah! But using a tap means that you rely on what's called the 'human element'. That's why these valves are fitted to do things automatically —without people being involved."

"*Mr. Stevens told me they make chocolates with them!*"

"That's right, but not exactly to *make* chocolates, to *help* make them. Mushrooms too!"

"*Cor! I like mushrooms.*" *(Throwing away magnet)*
"*Can I have some for tea?*"



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The outer case incorporates a diaphragm dividing the case into high and low pressure compartments, each compartment being connected to the appropriate pressure side of the filter via capillary tubing. Any difference in pressure, and subsequent movement of the diaphragm, applies pressure to an overcentre snap-action spring giving magnified movement at one end. This actuates a vividly coloured thimble, which enters a transparent dome, and is immediately seen externally.

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Into partnership with VIM Packings go our Hydraulic Oils that have an unusually even viscosity through widely fluctuating temperatures—meaning high performance and less mechanical wear and tear.

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* A-W holder
Weight 14 oz

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Careful and clever design of the long handle has resulted in greater ventilation, which enables the welding operator to complete all the extra 'hot-jobs' without discomfort.

The fully insulated, replaceable crown jaws of the latest Lincoln-Jackson holders ensure greater heat resistance and durability. The jaws are made of 98% copper alloy, which is treated for greater hardness and conductivity, yet the Holders remain feather-light in weight.

The insulation of both these excellent electrode holders gives full protection from accidental arcing to the welding operative and his work throughout the entire operation.

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For a reliable performance and superlative efficiency, the new Lincoln-Jackson Electrode Holders A-W and JH-2 are undoubtedly the best available in the United Kingdom.

* JH-2 holder
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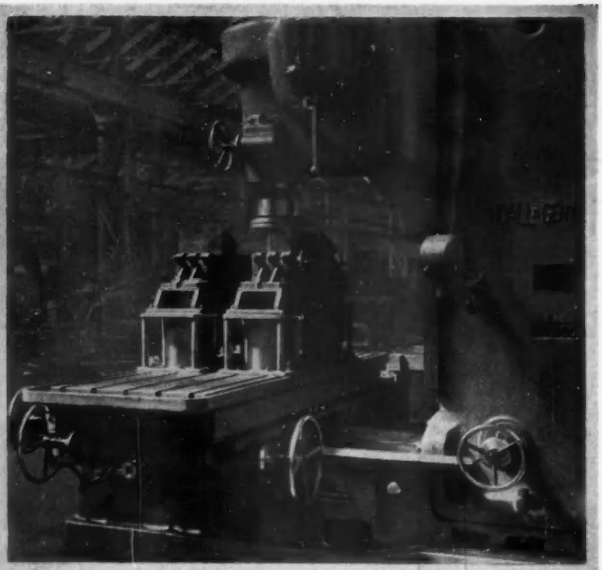

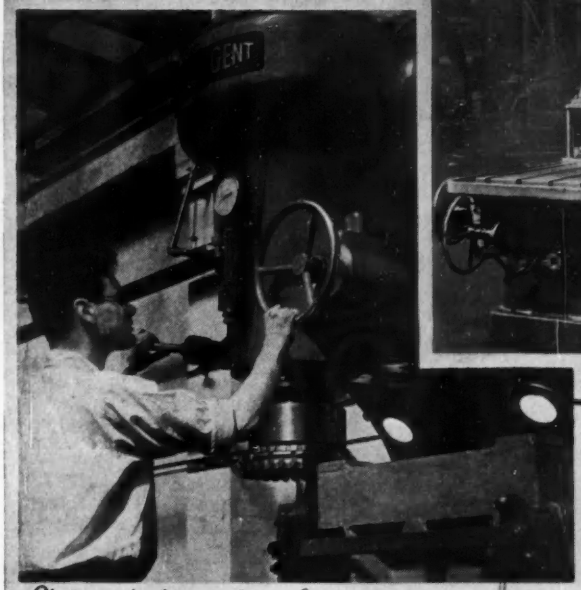

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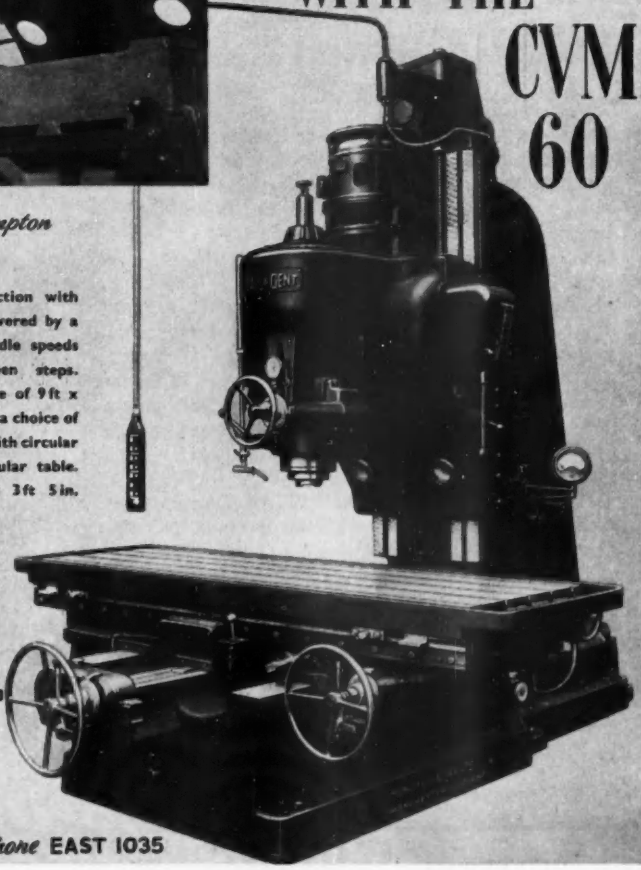
WITH THE CVM 60

THE CVM.60 combines maximum production with extreme accuracy and easy operation. Powered by a 25 h.p. or 40 h.p. motor as required, spindle speeds range from 15 to 840 r.p.m. in eighteen steps. Rectangular table type has working surface of 9 ft x 2 ft 9 in, and traverses 7 ft 2 in x 3 ft 3 in, with a choice of four feed ranges. Other models available with circular table or combined circular and rectangular table. Maximum height under spindle nose is 3 ft 5 in.



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GROMMET V-BELTS*

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SPEEDICUT

BRITAIN'S
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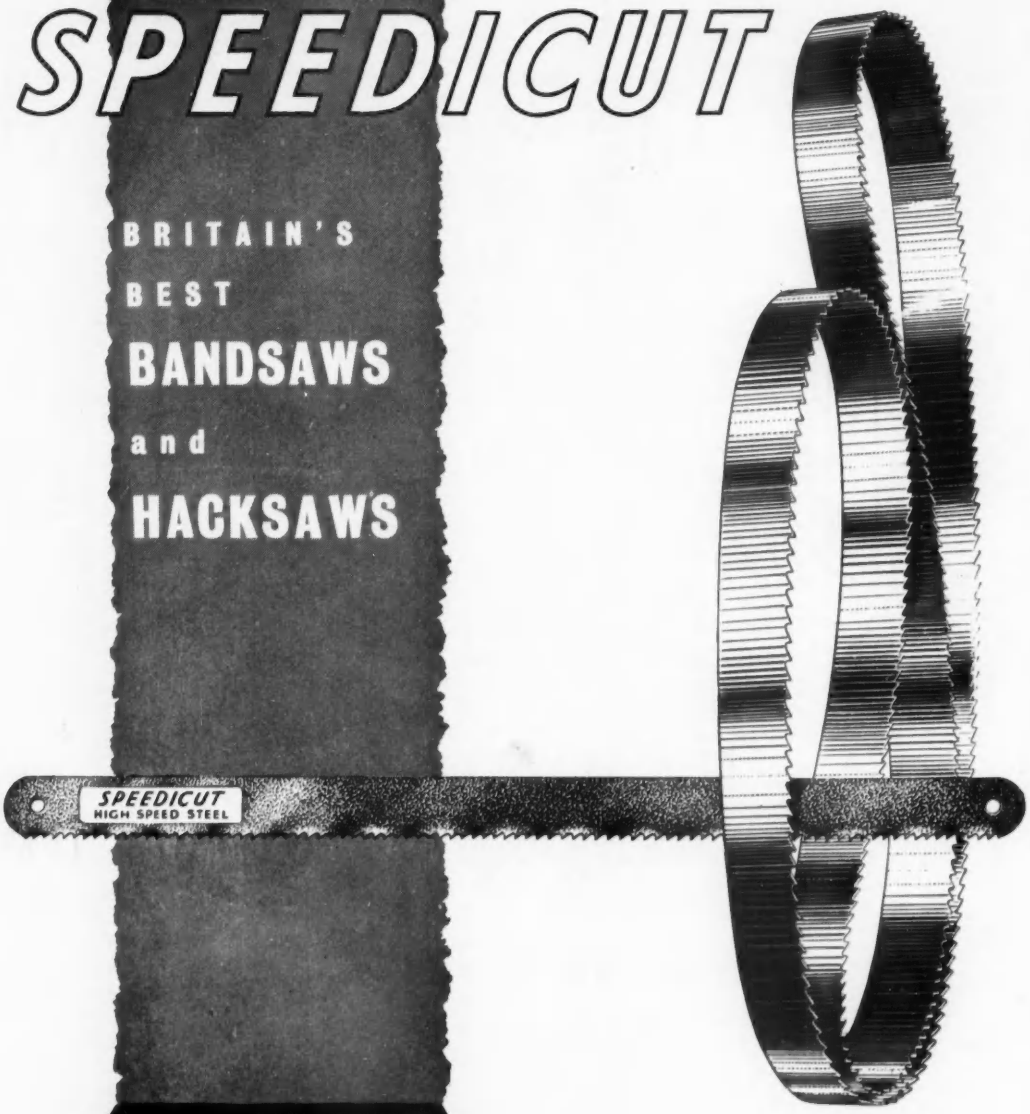

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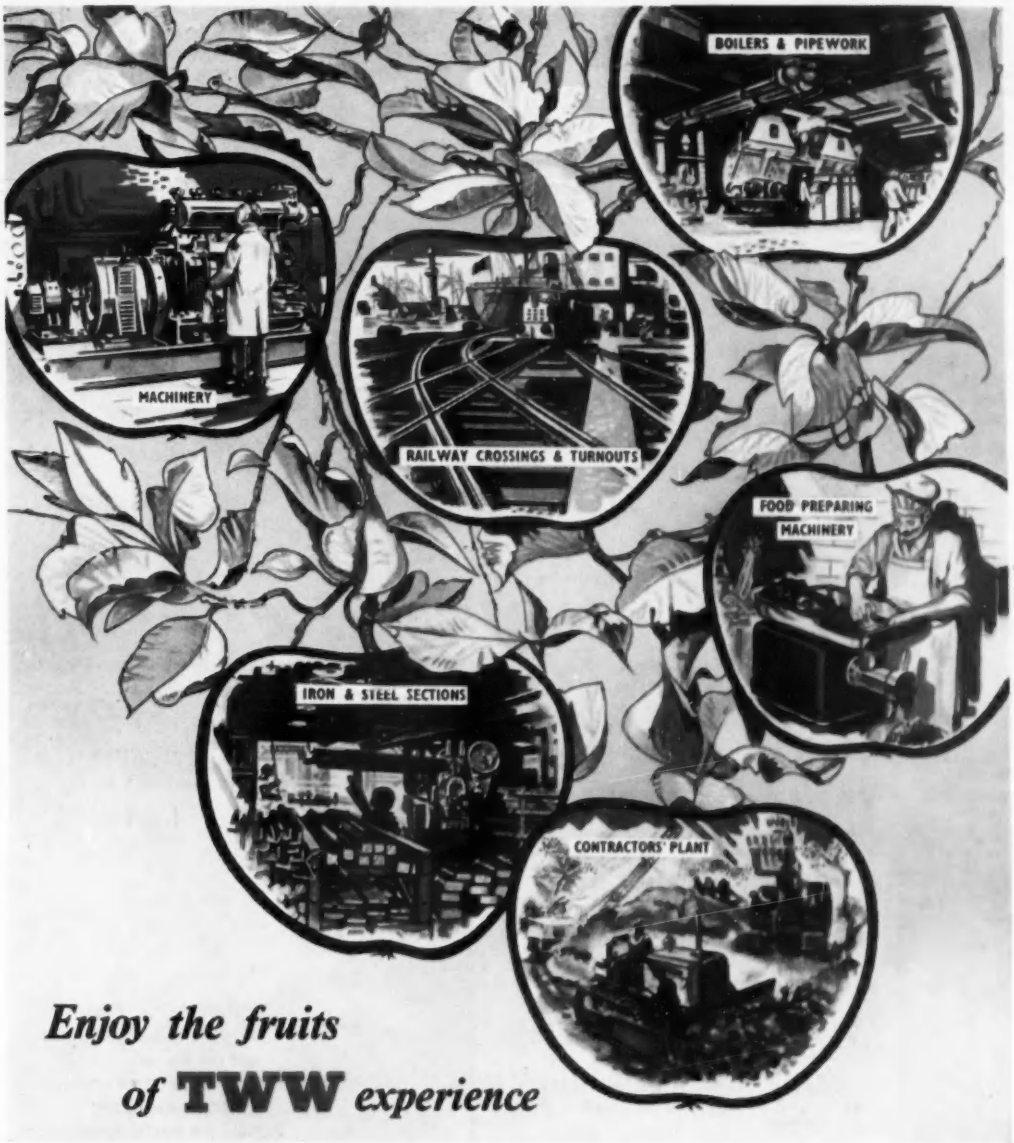

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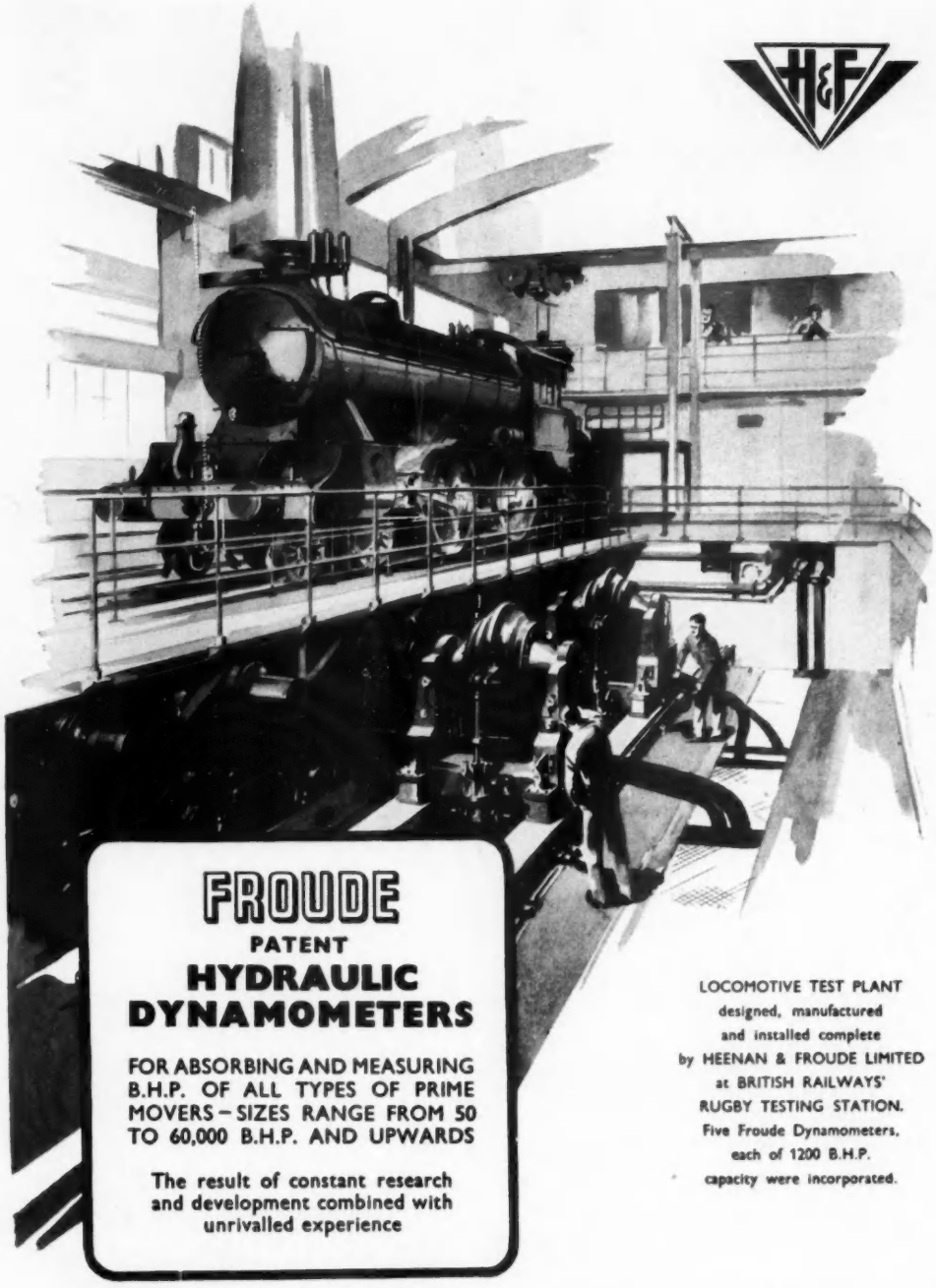

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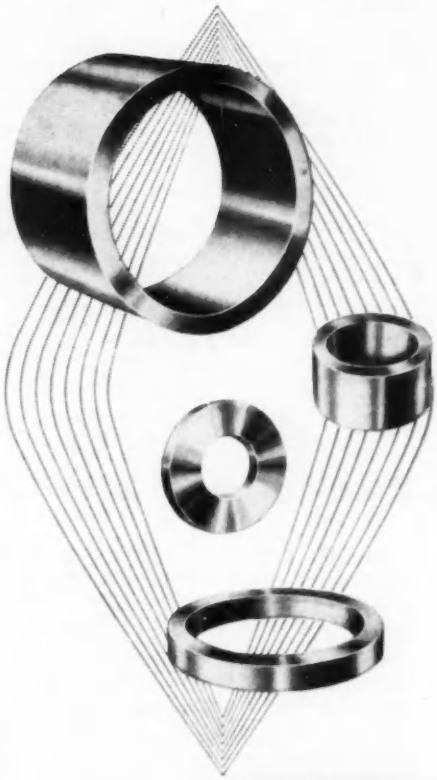
centrifugal force

the governing factor



The steam engine governor is a classic example of the application of centrifugal force.

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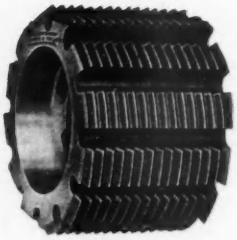

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K.E.High Grade Special Steels have long been renowned for their regularity and the close limits of analysis to which they are made. In addition K.E.Service before and after sales includes technical advice and Heat Treatment by us, if required, of any components made from K.E.Steels.

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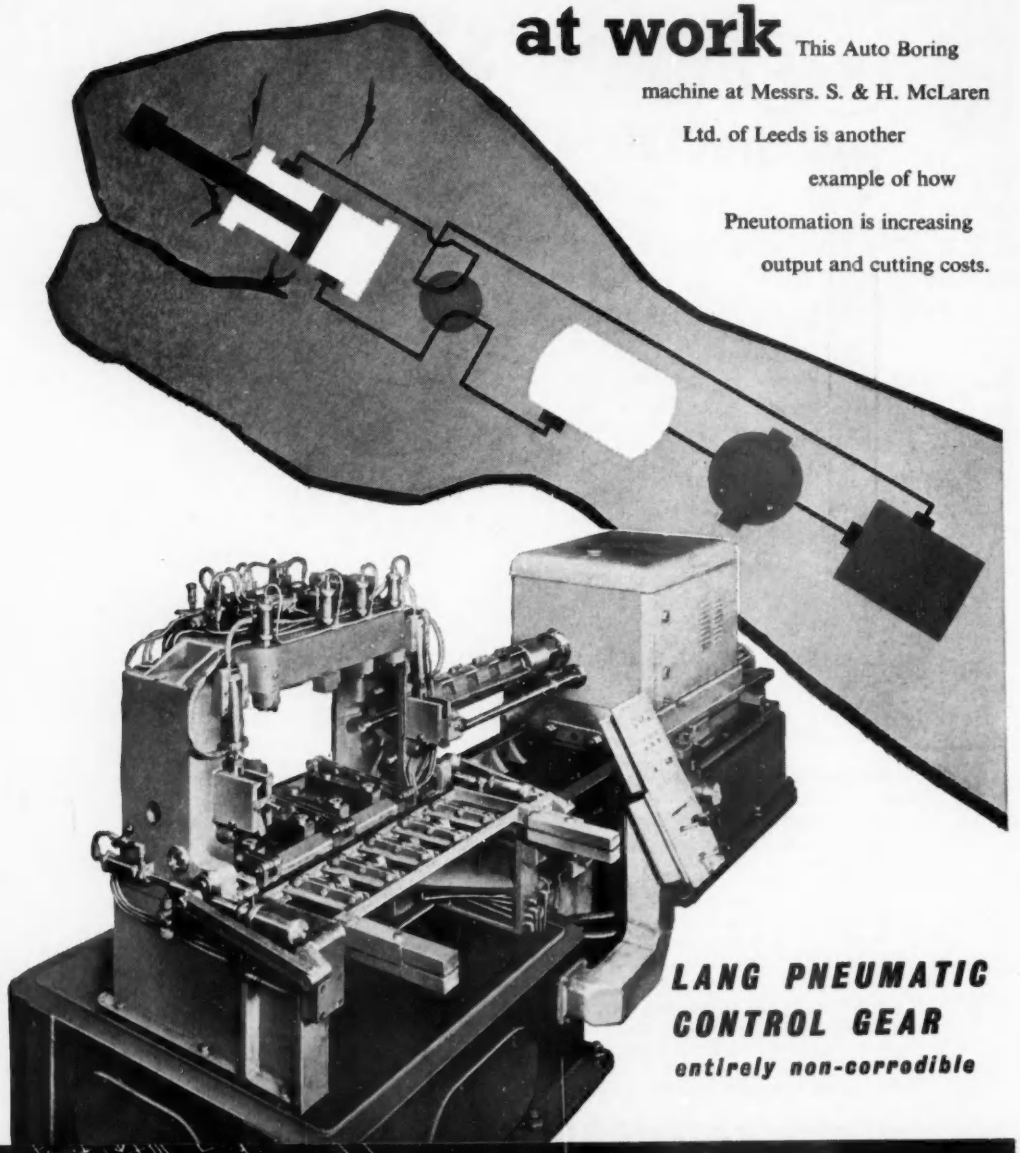

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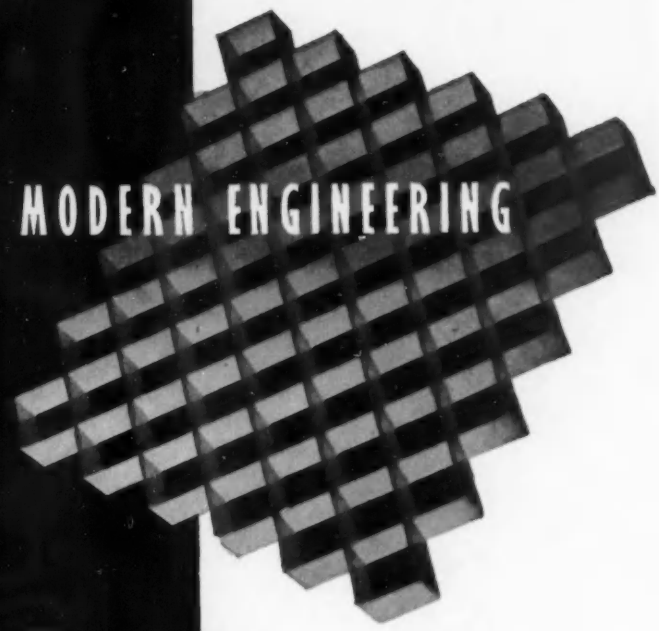

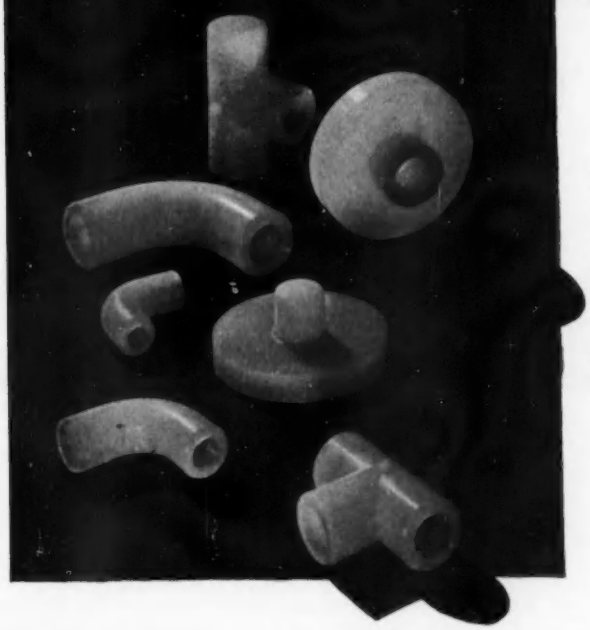

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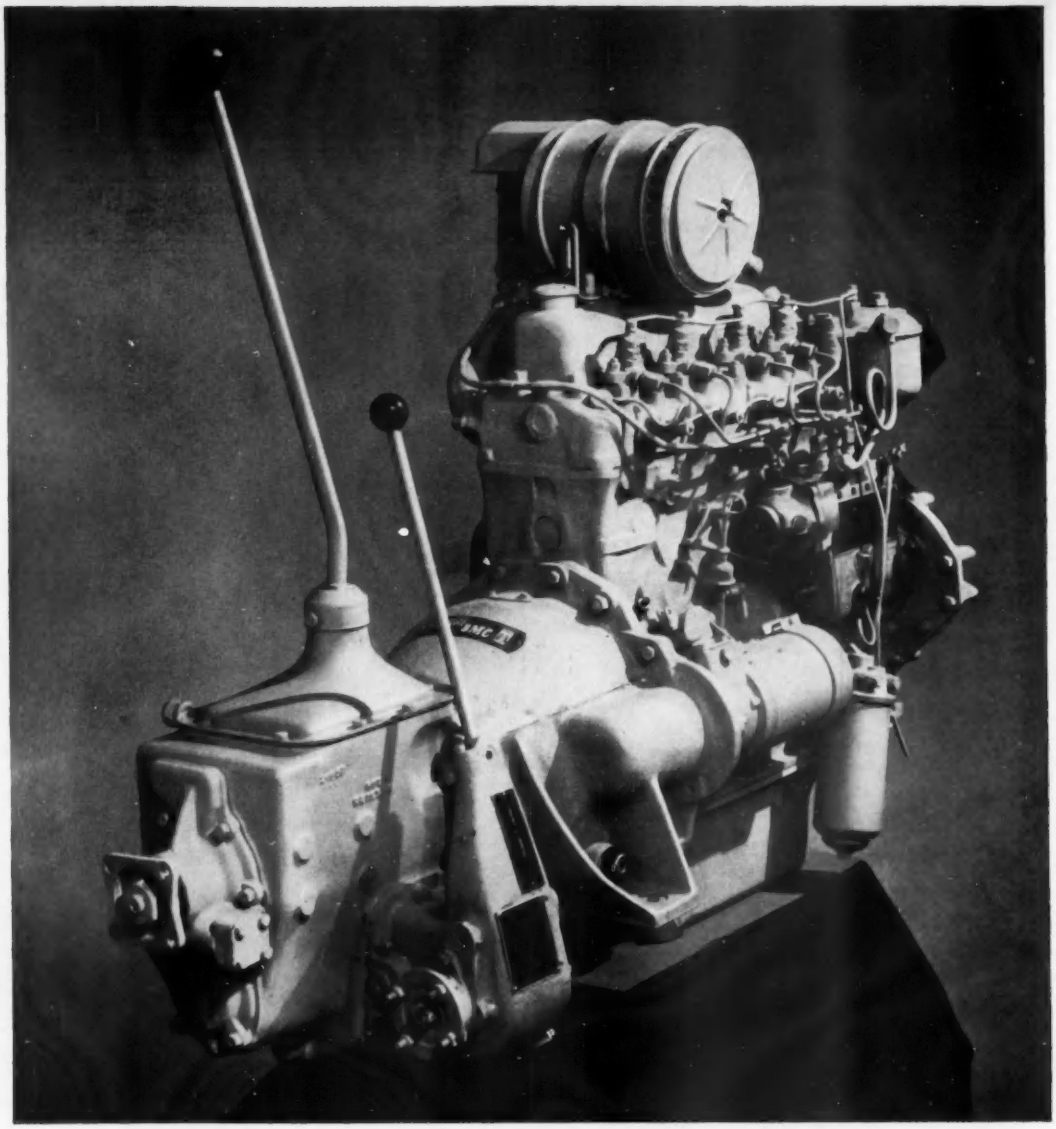

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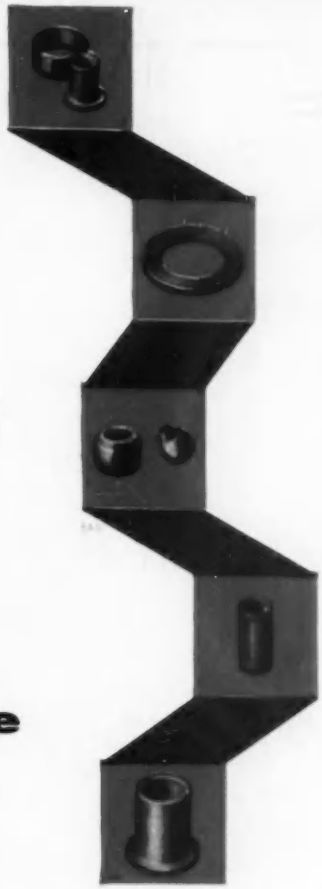

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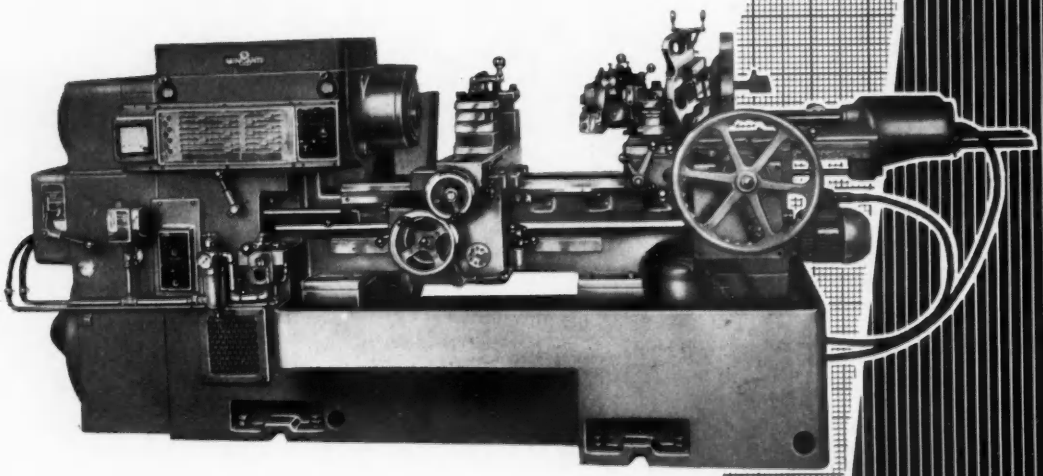

Standardized spindle end	ASA 6"
Dia. of hole in spindle	2¼"
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Max. distance from spindle flange to hex. turret	25⅝"
Max power required	HP 4·8—8
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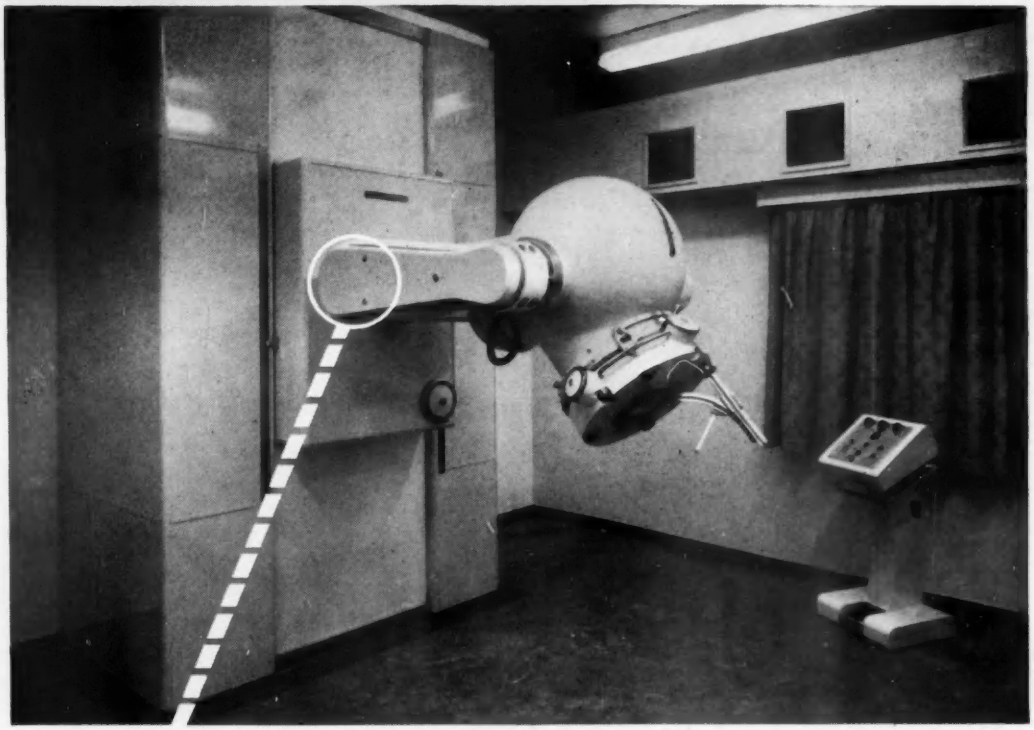

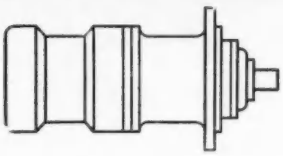

IN NUCLEAR ENGINEERING

The photograph shows a teletherapy unit using radio-active cobalt installed at the London Clinic. Messrs. Nuclear Engineering Ltd., Greenwich, are the manufacturers of this unit. A motorised Heliocentric Speed Reducer as depicted in the line drawing at the left, rotates the head weighing approximately two-tons, at a speed of one-third revolution per minute. Engineers not already familiar with the advantages of Heliocentric Speed Reducers are invited to write for a copy of a comprehensive fully-illustrated brochure. Range of manufacture ⅛ h.p. to 30 h.p., ratios 20:1 to 512,000:1.

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This untouched photograph is more effective than any words to illustrate the superb accuracy of Hancock machines. Made with precision and working to precise limits, Hancock oxygen cutting and profiling machines are the finest made today. No manual but a "Hancomatic" with electronic control could cut this electric motor rotor and plate. The template used is one of the rotor segments.

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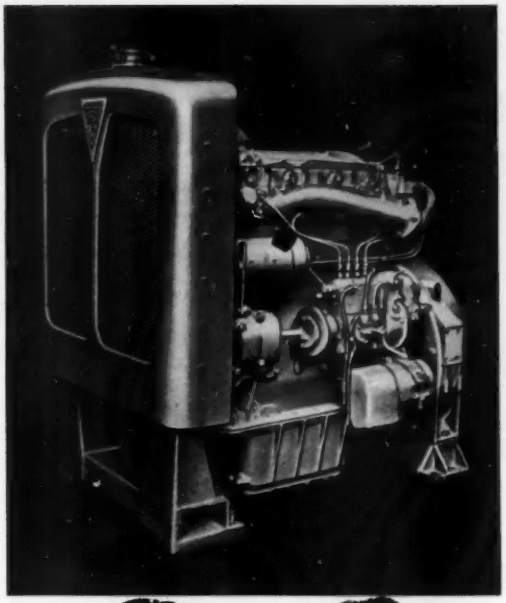

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This new 4-cyl. Industrial Diesel Engine has been designed by A.E.C. and Maudslay for earth moving and industrial equipment in which ample power is provided by an engine with a maximum output of 75 b.h.p. and a continuous rating of 50 b.h.p. It has all the features of the existing range, top performance, reliability in the severest working conditions, consistent operating economy —and interchangeability of working parts.
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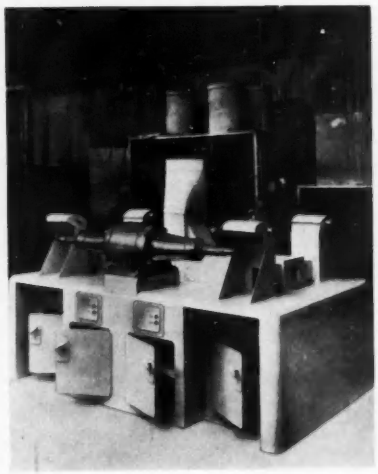

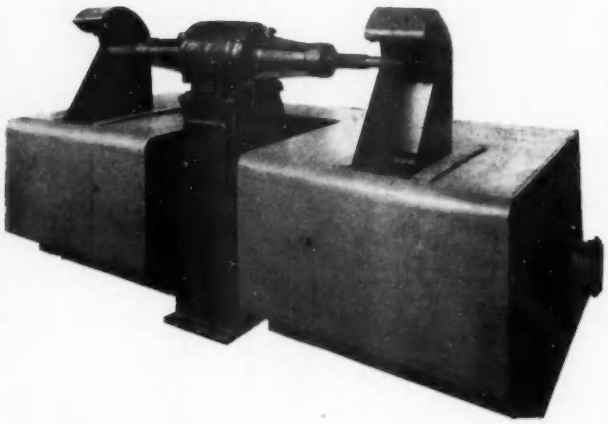

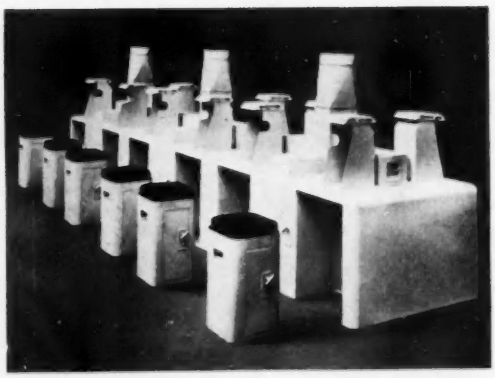

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Maximum face width..... 1"

Coarsest pitch..... 16 D.P.

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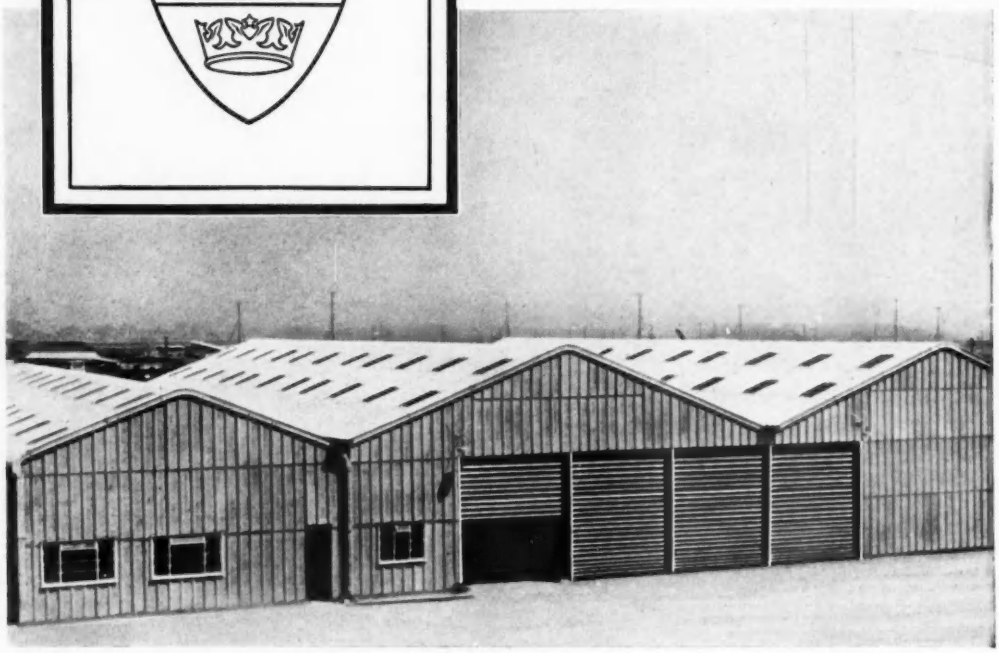

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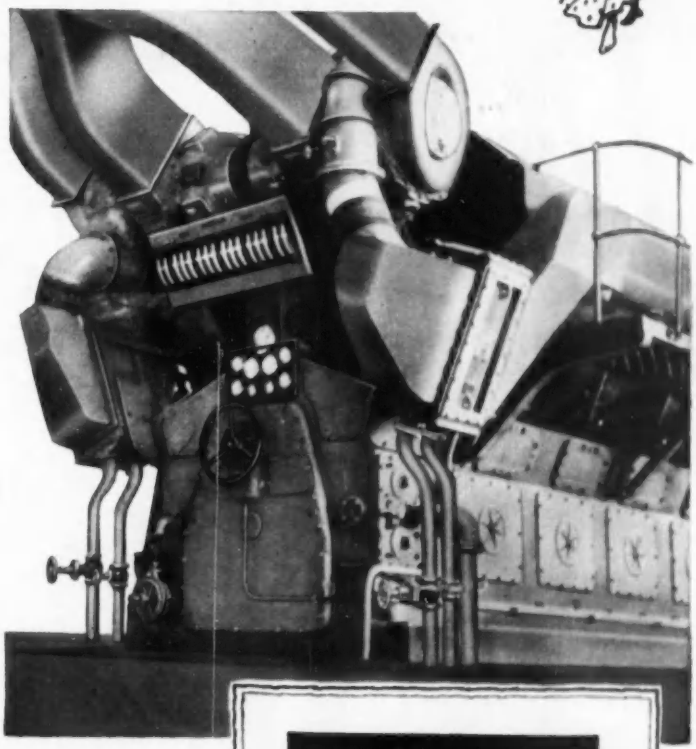

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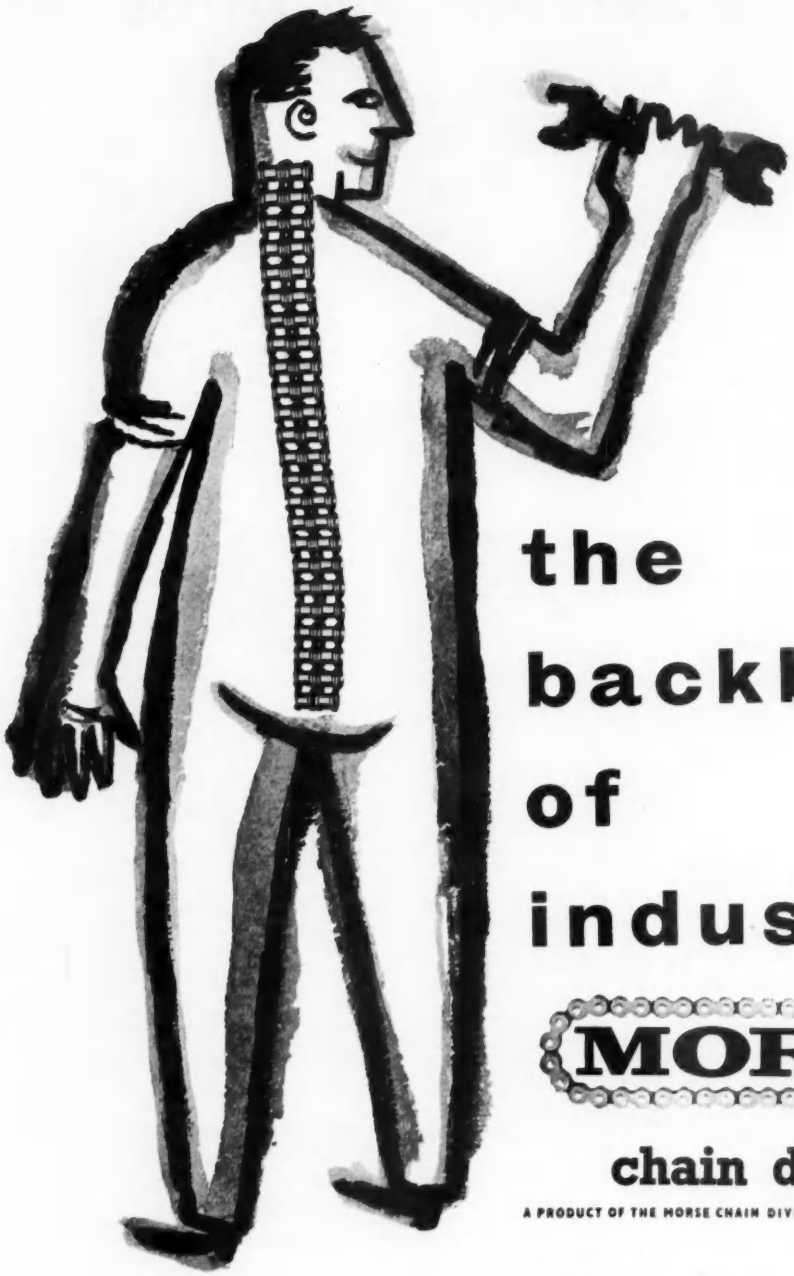

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chain drives

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Sizes ¼, ½, 1, 2, 3, 5, 7½ and 10-tons. Types for fixed, suspension, push travel, geared travel or for electric travel.

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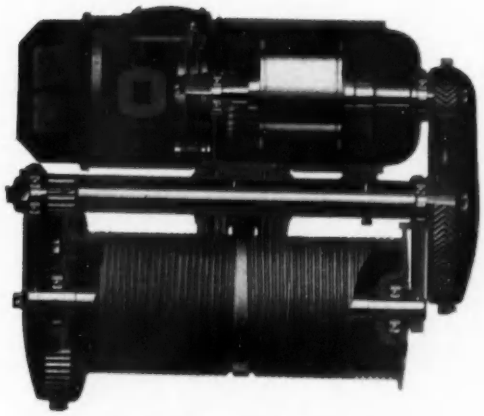
ALL-BRITISH BALL-BEARING ELECTRIC HOIST-BLOCKS



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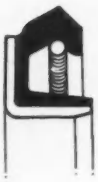
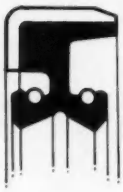
TYPE 11 P/B

As type 11 P but with the casing covered with rubber. Interchangeable with metal case seals.



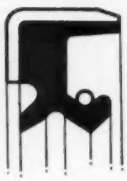
TYPE 23 P

An external seal used when fitting conditions prevent the use of 11 P or 11 P/B seals.



TYPE 12 P

A rotary shaft seal used to separate two different fluids.



TYPE 13 P

Similar to type 12 P but without a spring on the second lip which serves as a dust excluder.

TYPE 31 P

A springless seal used as a wiper or dust excluder for rotating or reciprocating shafts.

NU-LIP RINGS

A special section ring which cannot twist. Superior to the O-ring for low and medium pressure non-static applications.

O-RINGS

A compact automatic seal for reciprocating and static applications over a wide range of temperatures and pressures. All British Standard sizes in stock.

TYPE 7 P

A hydraulic and pneumatic seal used chiefly on reciprocating pistons or as a valve stem packing. Normally fitted in a groove.

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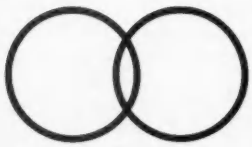
The PIONEER man is trained to solve your sealing problems on the spot. Call him in now.



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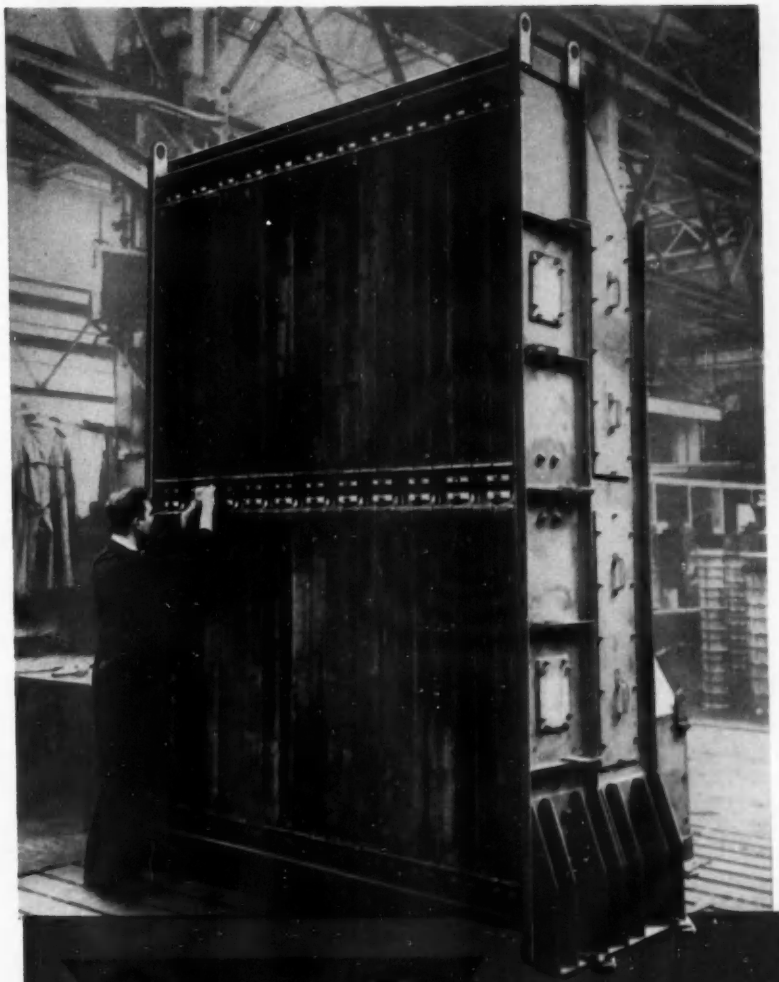

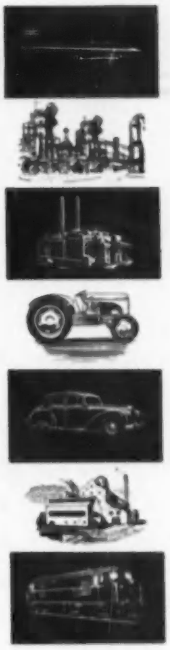

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FOR TOTALLY ENCLOSED ENGINE COOLING SYSTEMS

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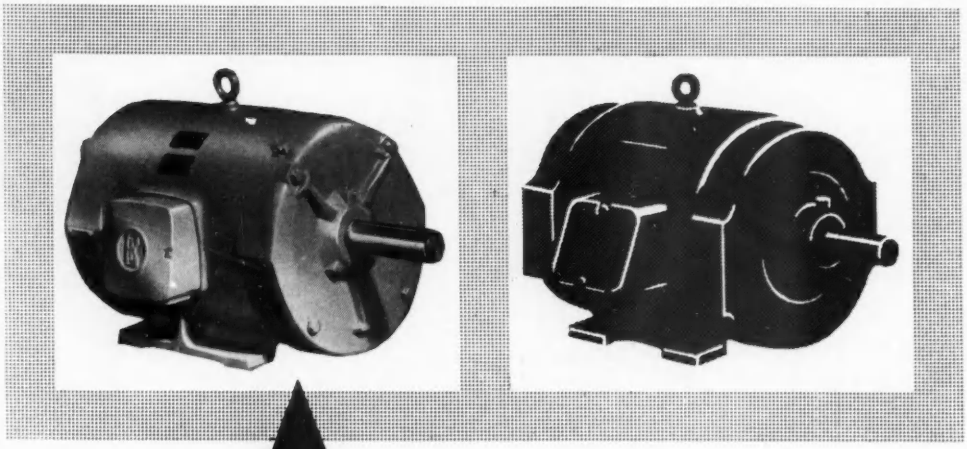

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Revolving Frame and Bridge Casting for 22-RB excavator. Weight as cast 2 tons 14 cwt. Sectional thickness max. 2½" min. ½". Cast for Ruston-Bucyrus Ltd., by whose permission it is reproduced.

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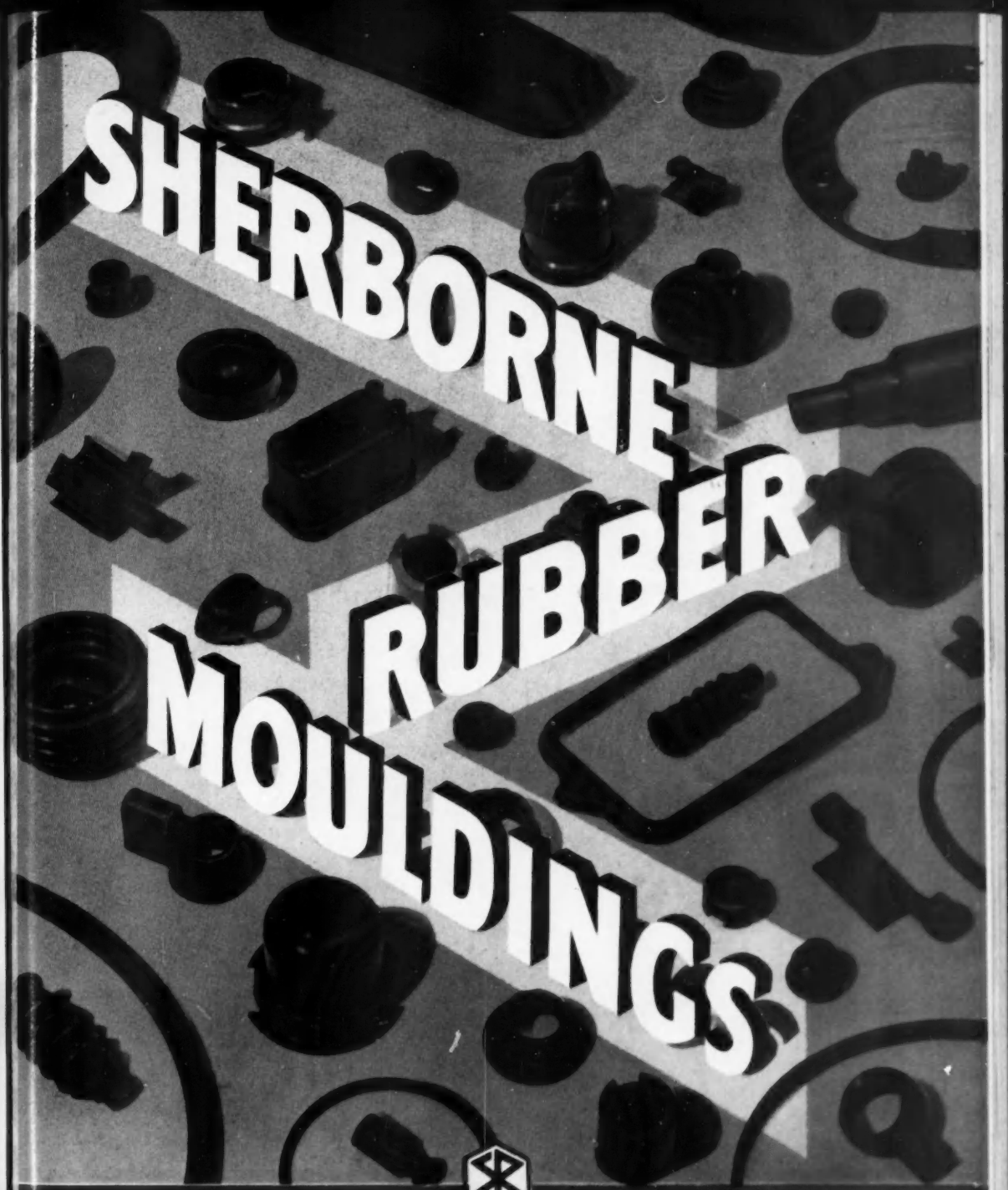

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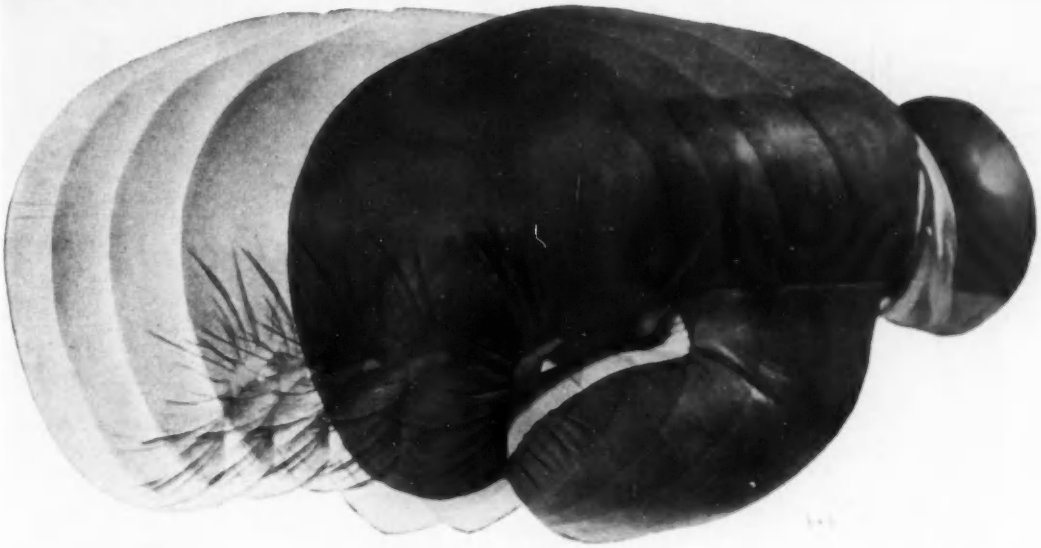

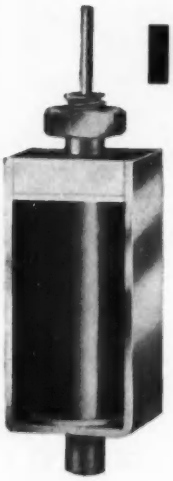

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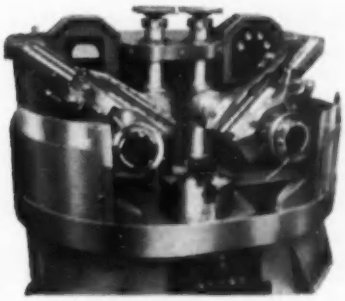

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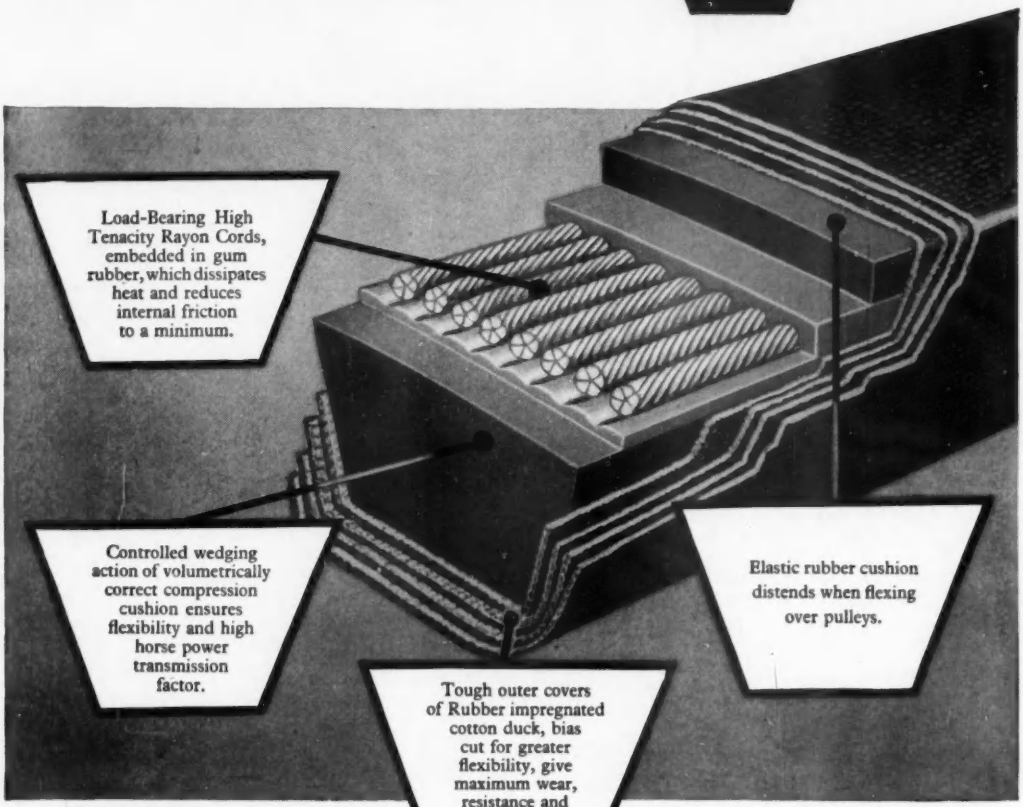
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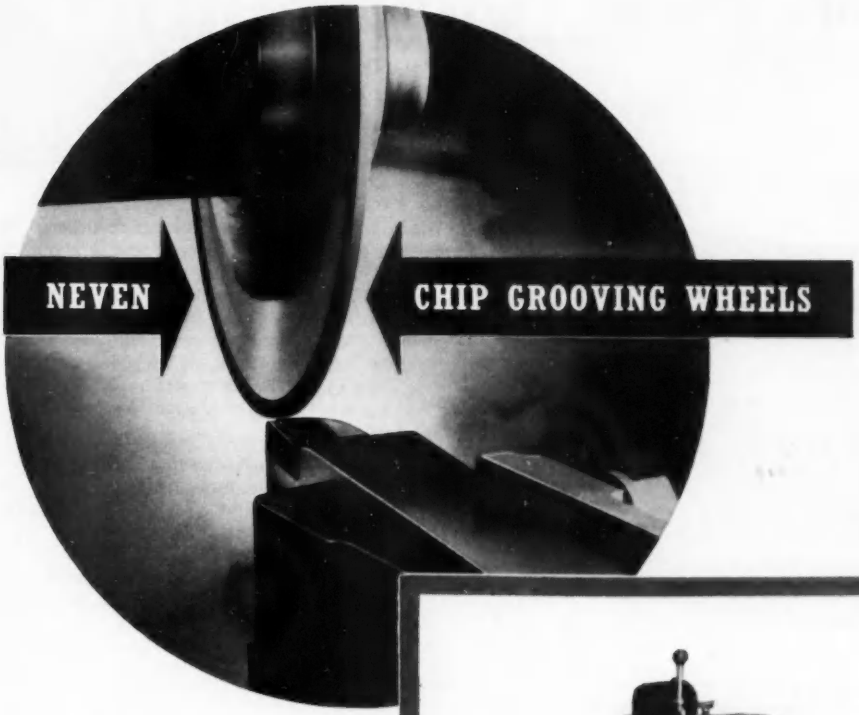

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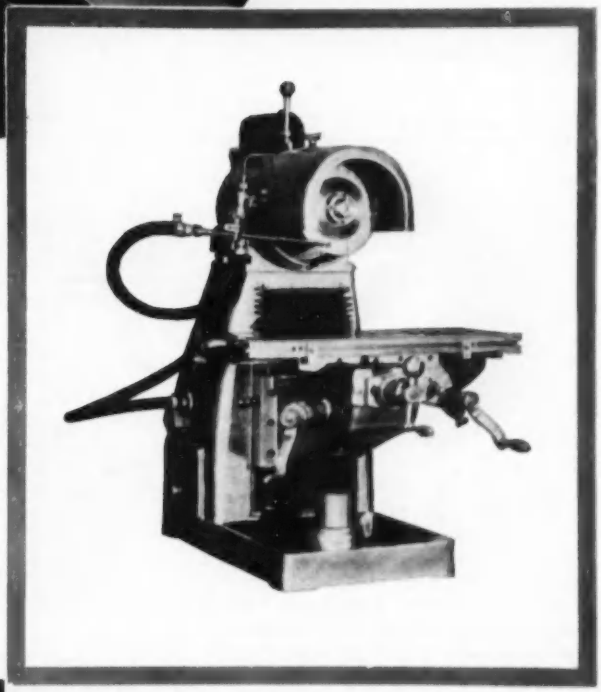

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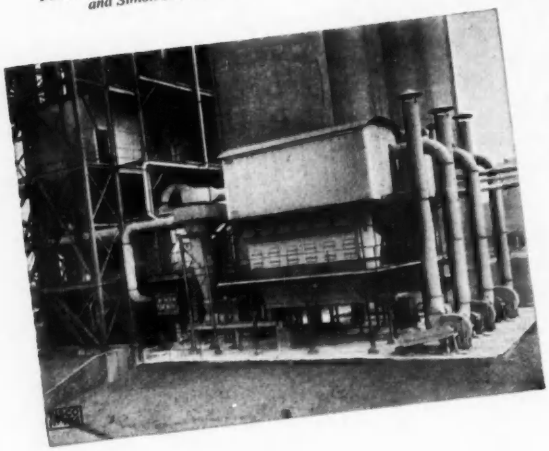

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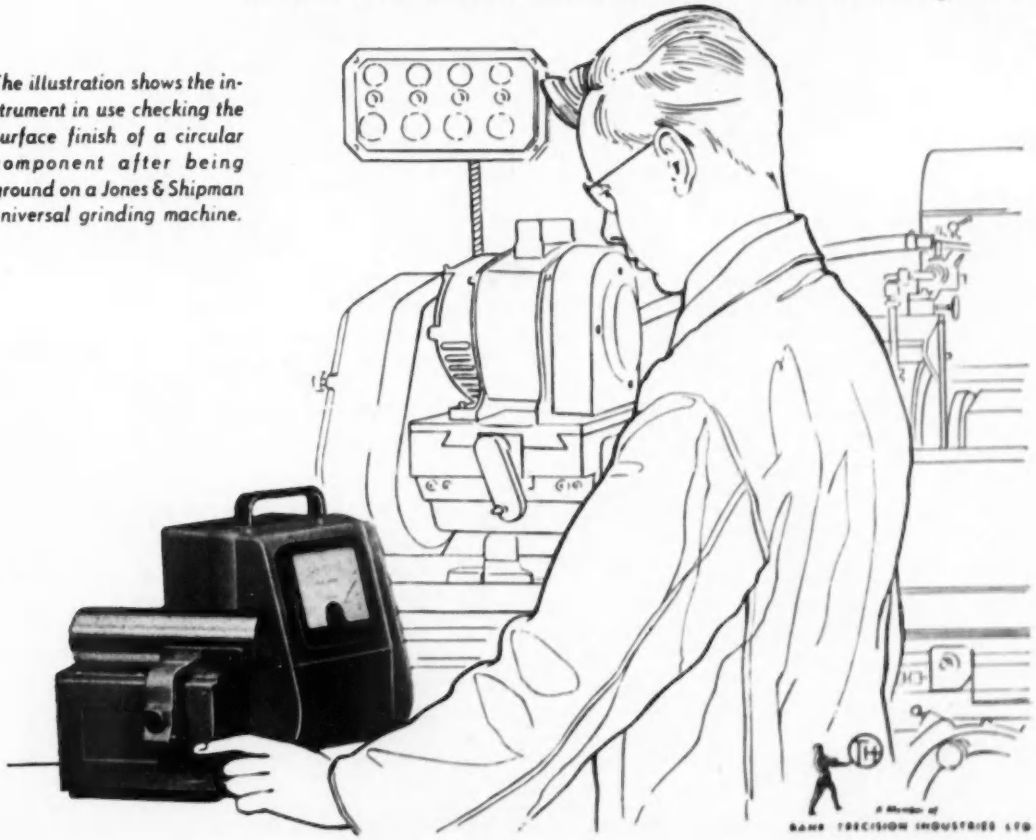

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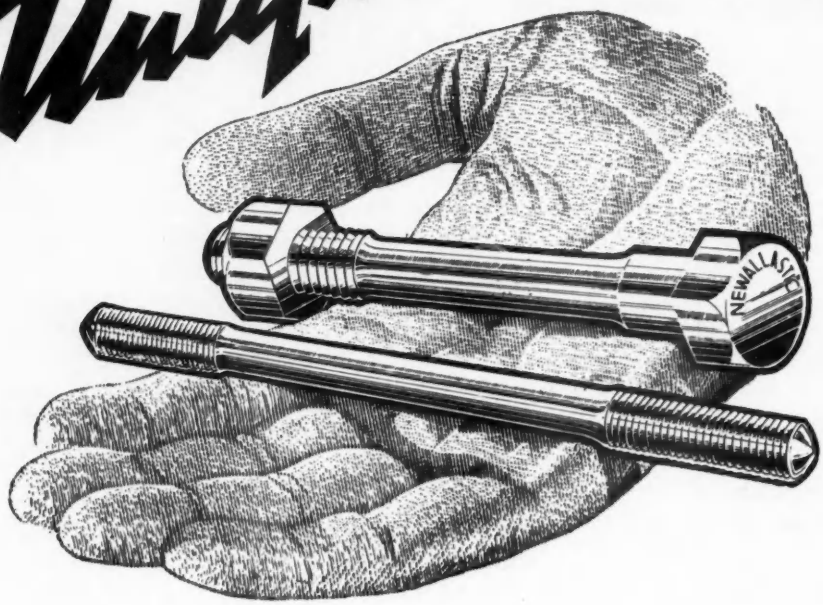

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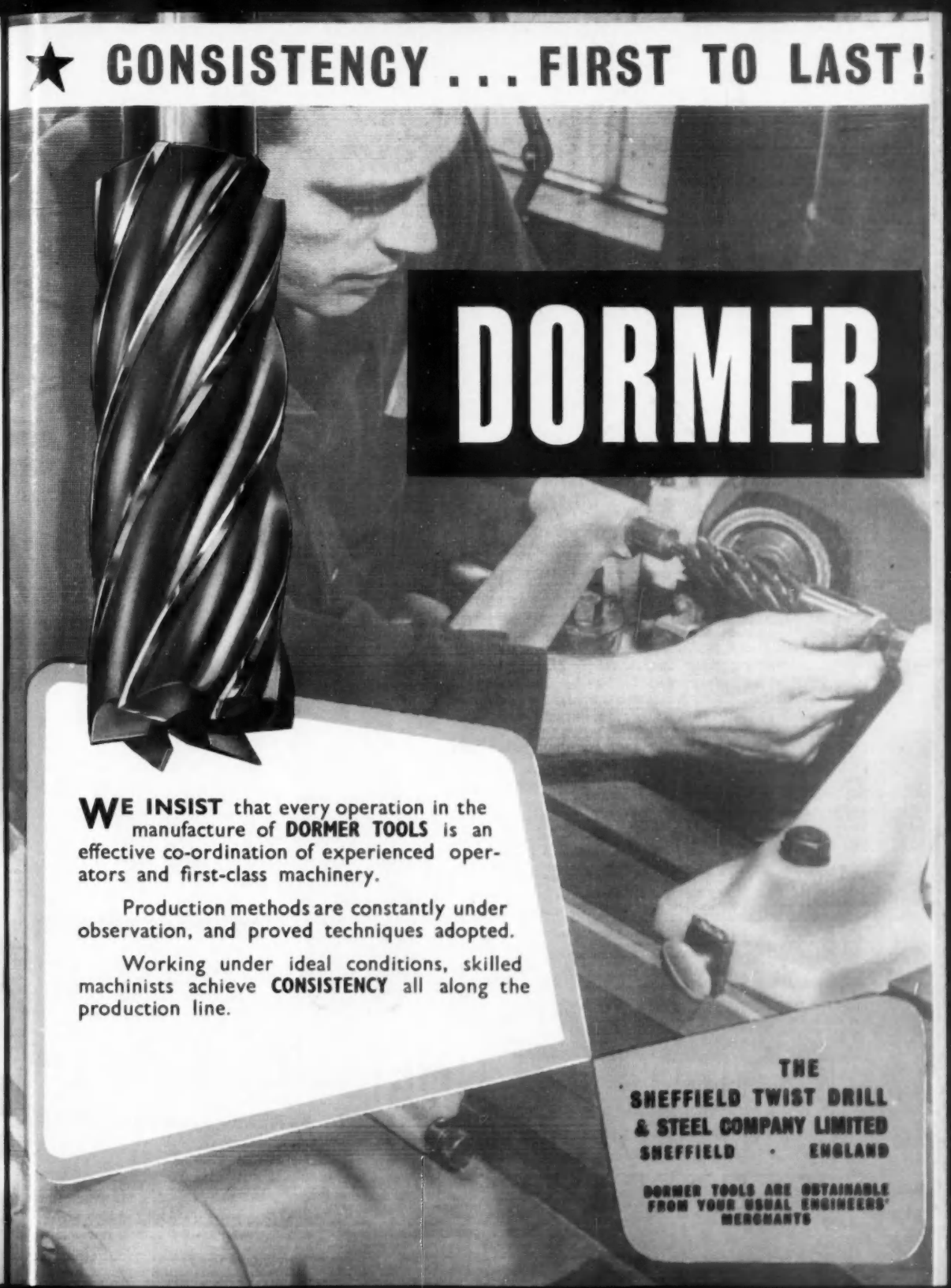

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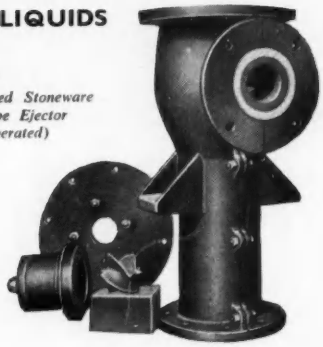

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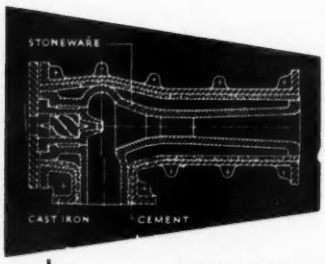

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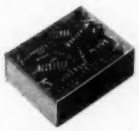

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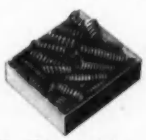

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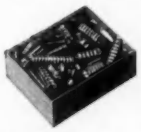

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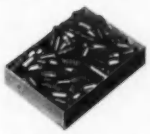

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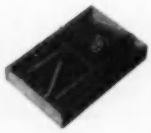

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ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIX NO. 2 FEBRUARY, 1958

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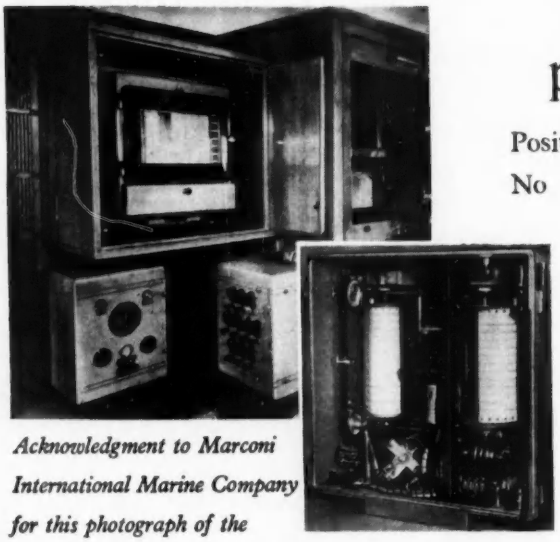

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *IMPROVED IRRADIATION TREATMENT FOR MATERIALS*

An improved process has been proposed for the treatment of materials by irradiation with high-energy charged particles, to change the chemical or physical properties of the materials, which may be solids or liquids contained in suitable vessels. The particles used in the irradiation treatment are preferably electrons with an energy of 0·5 MeV and higher, and during treatment the body is moved continuously past the source of electrons in a direction tranverse to the electron stream directed upon the body. The particle beam may be oscillated to scan the body to be treated, i.e., magnetic or electrostatic deflecting means, similar to those employed in cathode-ray tube technique, may be made to act upon the beam before it reaches the body to be treated. The oscillatory motion of the beam with respect to the body may be either transverse to or parallel with the direction of the body, or both motions may be combined. An important feature of the new process is that a first part of the beam impinges on one side of the body and a second part passes the body and enters a substantially uniform magnetic field, by means of which it is deflected back to impinge on the opposite side of the body. For this purpose a substantially uniform and constant magnetic field is arranged transversely to the general direction of the beam, to be deflected through approximately 180 deg. in a curved path, which will generally be circular or spiral. A particular example of the application of the process is the treatment of an electric cable, in which penetration of the particles through the whole of the body is obstructed by the conductor. Here, the new process dispenses with the necessity for rotating the cable as it passes through the beam, or of passing the cable twice through the beam in such a way that in successive passages opposite sides of the cable are exposed to the beam.

● *IMPROVED SONIC GAS ANALYSERS*

The sonic or acoustic gas analyser depends on the fact that the velocity of sound varies from one gas to another, so that variations in composition can be related to changes in velocity. The source of sound can be excited electrically at a constant frequency, some of the acoustic energy being received by a microphone located at a given distance from the sound source. However, a serious difficulty found in operating sonic gas analysers arises through the formation in the analysis tube of stationary waves which are produced by the interaction between the direct wave from the transmitter and the wave after reflection from the end of the tube. In a recent patent it is proposed to eliminate or reduce substantially the effect of the stationary wave by packing the analysis tube with a material having interstices which provide continuous passages through the material, so that sonic or ultrasonic vibrations can be transmitted through the material by way of a gaseous medium. Suitable materials include plastics such as polyethylene, metallic granules, or small pieces of glass. The choice of material will depend to some extent on the nature of the gas to be analysed, but in general the properties of the material should be such that it is impervious to the gas under analysis and to water vapour. The action of the tube-filling in eliminating standing waves is due to the fact that a weak reflection will occur at each particle surface, and at any given point in the tube a multitude of reflections with all possible phase relationships will be received. These reflections will, however, cancel each other and there will be no interference with the direct wave. The effective path length for the sound may differ a little from the value obtained with the empty tube, but this is of no consequence, provided that it remains constant.

● *GRAPHITE BODIES OF HIGH BENDING AND TENSILE STRENGTH*

Shaped bodies made of graphite or carbon are used to an increasing extent for industrial purposes. This is due to the extraordinary corrosion resistance of the material, combined with its good electrical and thermal conductivity. Graphite, however, has a small resistance to breaking and this is a great disadvantage in the case of elongated bodies such as thin-walled tubes or thin sheets. A recent invention aims at eliminating this shortcoming by providing the graphite body with iron, steel, or preferably nickel-steel reinforcing elements, attached to the graphite by means of synthetic resinous condensation or polymerization products, or a glycerol or rubber cement. The metals to be used as reinforcing elements may be in a great variety of forms and may be combined with the graphite body in various ways. They may be used, for instance, in the form of rods, wires,

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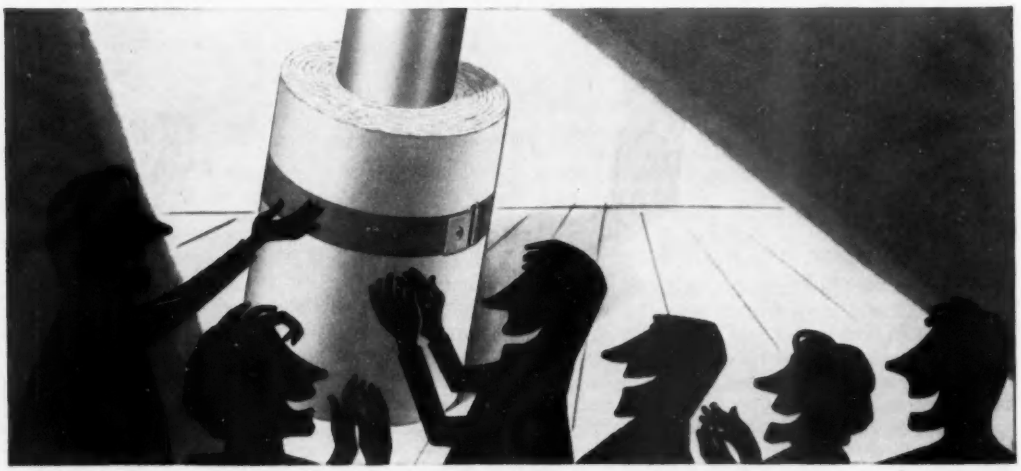

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strips, or bands of any desired cross-section. In graphite rods and tubes, as also in graphite sheets, the reinforcing metal elements may be mounted on the surface of the graphite body or in recesses made in the body. When selecting the cement to be employed, the intended use of the graphite body must be taken into consideration. Thus, in cases where the graphite component is to be exposed to elevated temperatures, heat-resistant cements will have to be used. The cements containing artificial resins may contain hardeners and fillers. Where impregnated tubes are concerned, for instance for heat exchangers, the rods or wires are embedded in the artificial resin in one operation with the impregnation of the tube, by immersing the tube in the liquid resin and then subjecting it to a heat treatment. An exterior coating of hardened artificial resin produced at the same time can then readily be removed by turning at the part of the outer tube wall to be used as the heat-exchanging surface.

● *HARD INTERMETALLIC COATINGS FROM ELECTRODEPOSITED REFRACTORY METALS*

A recent invention is concerned with the formation of hard metallic surfaces or layers on metals, and is based on the discovery that hardened surfaces composed of titanium and certain other refractory metals, e.g., hafnium, tantalum, and tungsten, can be produced on a base metal by a special procedure, involving the formation of a cladding layer of the refractory metal and then causing the transfer of a refractory metal-hardening element from the mass of the base metal to the cladding layer of the refractory metal. If a layer of a hard intermetallic compound of a transition metal such as titanium, zirconium, hafnium, vanadium, tantalum, or tungsten, etc. is to be formed, a fused salt bath, composed essentially of a halide of the refractory and a diluent halide salt, is prepared. It is essential that the base metal to be coated contains an intermetallic compound-forming element such as carbon, nitrogen, boron, or silicon. The part to be coated is then immersed in the salt bath, and, by making the part the cathode and the salt bath the anode, a refractory layer is formed on the cathode. The part bearing the deposited layer of refractory metal is then heated sufficiently to effect thermal diffusion of the intermetallic compound-forming element from the base metal into the refractory layer. Typical base metals are iron and steel, but other metals and alloys, e.g., copper, brass, bronze, nickel, etc., are capable of being provided with a hard surface in this way. However, in every case it is a prerequisite that the base metal should contain at least one of the compound-forming elements mentioned, which may be present in the base metal either as a component uniformly distributed throughout the entire body of the metal, or present in large part or even exclusively in a relatively thin surface layer of the base metal. The thermal diffusion of the intermetallic compound-forming element from the base metal to the refractory metal promotes the formation of a strong physical bond between the base metal and the resulting hard facing.

● *CRYSTALLOGRAPHIC RESEARCH IN STRESS CORROSION*

It is reported that small crystals in a hitherto unobserved form may furnish an explanation of the cause of stress-corrosion cracking in metal structures. The newly discovered crystals grow as delicate plates from the surface of stainless steel exposed to atmospheres containing traces of chloride ions, and it is believed that their growth on the steel surface could lead to a chemical cutting of the metal. Minute crevices might grow downwards into the metal surface as the platelets thrust themselves above it, possibly leading to stress concentrations at the base of the crevices and eventually causing metal failure. In the case of an unstressed stainless-steel wire exposed to pure oxygen and water vapour at 1100°F, for instance, the wire surface was found to become covered with innumerable oxide "whiskers", about 2 microinches in thickness and from 600 to 800 microinches in height, the number of these whiskers approximating 6×10^9 per square inch. When stressing the specimen and adding less than five parts per million of chloride ions to the atmosphere, in place of long thin filaments parallel plates growing along a definite crystallographic direction are formed, their thickness being 0·5 microinch or less. Analysis has shown them to have the characteristic structure of an oxide of chromium (Cr_2O_3), and each platelet appears to be a single crystal of the oxide. It has been known for some time that the chloride ion is a major factor in producing stress-corrosion cracking of stainless steel. It now appears that the chloride ions can stimulate the growth of these plate-like crystals in a strongly stressed metal, and this growth might result in cracking and ultimate failure of the steel.

● *TRAILING ANODE FOR THE CATHODIC PROTECTION OF SHIPS*

A recent report claims that the installation and maintenance problems of hull-mounted cathodic protection of ships, as well as its variations in performance, can be overcome by using a trailing anode. By this method, the anodes are removed from the hull proper and consolidated into one light-weight streamlined high-capacity anode. Such an anode can be trailed far enough from the hull to equalize sea-water path resistance between the two members, so

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that essentially uniform current paths are produced to all parts of the hull. The trailing anode consists of a 90/10 platinum/palladium alloy cladding, 0·005 in. thick, on a silver rod, 48 inches in length. The major portion of the anode has a section of $\frac{1}{4}$ in. dia., gradually opening out to $\frac{1}{2}$ in. dia. at one end. The cable attachment and insulated connection are made at the flared end and streamlined. The other end of the anode is capped with a platinum-alloy thimble, sweated in place with silver solder. A polyester-resin sleeve is moulded on the thimble end for further protection of the joint. The cable is a polyvinyl-sheathed flexible conductor, about 200 ft in length, attached by silver soldering to the silver rod. The platinum anode has proved itself an effective and comparatively simple cathodic protection system for a small boat or ship in port and at sea. Platinum anodes remain clean in service and do not build up resistance films on their surface. The ease with which the platinum anode can be trailed under service conditions and also its high current-handling capacity are claimed to make the system easily adaptable to larger ships.

● ***CONTOUR FORMING OF DIAMOND-IMPREGNATED GRINDING WHEELS***

In the machining of dies and tools of tungsten carbide it is desirable to have a diamond-impregnated grinding wheel which has a contour of highly accurate dimensions, so that an accurate cut of the desired contour can be made by a small number of passes of the grinding wheel. A recent patent describes a method which makes it possible to profile the contour of a diamond grinding wheel to within 0·0002 in. of the specified dimensions. This method consists of the use of an accurately shaped dressing wheel which rotates very slowly when applied to the diamond wheel. A particular feature of this method is that only a small peripheral surface of the dressing wheel is used for any one dressing operation, so that the dressing wheel can be used for a number of dressing operations before it requires re-shaping. The dressing wheel is made of aluminium oxide and is of the ceramic bonded type. The preferred peripheral speeds are about 1250 ipm for the diamond wheel and about 2·2 ipm for the aluminium oxide wheel, but generally the speed of the diamond wheel may lie within the range of 600 to 2000 ipm and that of the aluminium oxide wheel within 1·2 to 3·2 ipm. At these speeds the aluminium oxide wheel will be able to cut several profiles into the diamond wheel before it completes one rotation and has to be re-shaped. It is desirable to make the aluminium oxide wheel larger in diameter than the diamond wheel since, with more fresh peripheral surface, the aluminium oxide wheel will be able to re-shape the diamond wheel more often before being re-shaped itself. Allowances must be made for differences in the binder material for the diamond wheel, for depth of the profile cut to be made in the wheels, and for the pressure of the aluminium oxide against the diamond wheel.

● ***ELECTRICALLY HEATED FLUIDIZED BEDS***

Fluidization techniques in recent years have become an important feature in oil refining, and their application to fuel combustion has now entered the development stage. A recent invention envisages the use of electrically heated fluidized beds for various industrial and metallurgical processes, in which the comminuted substance of which the fluidized bed consists is in particles of such size that the individual particles are kept in suspension by the gas in which they are distributed. The gas may flow upwards, may be without any directed specific movement, or may carry the solid particles only because of its inherent heat motion. Heating of such a fluidized bed can be carried out in such a way that its properties as an electrical resistance can be utilized, e.g., by passing a current through it. It is claimed that, owing to the intensive internal movement of the suspended bed produced by the electric current and because of the powerful heat motion of the carrier gas, a very effective equalization of heat takes place throughout the bed. Electrodes can be immersed in the bed, or the bottom of the vessel enclosing the bed can form one electrode, with other electrodes introduced into the bed through the wall of the vessel. A typical application is stated to be the heating of hydrogen to 700°C. In this case, a suspended bed of iron-alloy powder can be used, the particles being kept in suspension by the hydrogen introduced into the bed from below and escaping at the top. Another application is the reduction of alumina with carbon, the bed consisting of alumina grains into which powdered coal is injected.

● ***IMPROVED METHOD OF ELECTROFORMING***

Electroforming is often used for the production of radio components, such as waveguides, where a hollow tube or body is required to be produced to close internal dimensional limits and where a smooth internal surface is usually desirable. Electroforming comprises the electrodeposition of a metallic material, e.g., copper, on a form or mandrel which is made externally to the dimensions and the standard of surface finish required in the internal surfaces of the final product. When the material has been deposited to the required thickness, the deposition process is stopped. The external surface of the deposited material is then machined, if required, and the form is withdrawn. In certain cases, however, such as waveguides with right-

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angle bends, difficulties arise, inasmuch as it is necessary to employ forms which cannot be withdrawn simply, while another problem is that of the deposition of the metal in the re-entrant angle of the form. It is now suggested in a recent patent specification that the problem of depositing material in the re-entrant angle can be solved by an improved electroforming method, in which the electrodeposition of material in an electrolytic bath is carried out with a conducting member positioned in relation to the re-entrant angle of the form in such a way as to guide an increased flow of current towards the corner of the angle during deposition. The conducting member, which is not connected to a terminal of the bath used for electroforming, appears to provide a path of greater conductivity in the electrolyte and thus picks up current from within the electrolyte, enabling it, by virtue of its greater conductivity, to guide the current to regions where it would not otherwise flow. The conducting member can conveniently be made in such a shape that pick-up of the current takes place at a broad face, and out-flow at an end edge or point located in the angle. As a preliminary step, a prefabricated member can be attached to the body being electroformed. This member carries an extension piece which tapers to the surface of the form and, as deposition proceeds, the extension piece becomes virtually part of the electroformed body.

● *EASILY FABRICATED FUSED SILICA MATERIAL*

It is announced that ceramic engineers have developed a new basic material for making special-duty ceramic objects, including rocket nose-cones and nozzles, from bonded fused silica grains (melted sand). This low-cost ceramic material can be easily fabricated into any desired shapes by dry-pressing or slip-casting. Fused silica for slip-casting is obtained in granular form, to be milled in water so as to form a finely ground suspension from which suitable shapes can be cast in plaster moulds. The primary problem has been one of determining the particle size distribution, mill additions, and milling conditions which would provide the required slip. The cast pieces are claimed to exhibit the excellent thermal shock-resistance characteristics of fused silica. The size or shape of the piece does not limit its ability to withstand severe shock; in fact, it can be heated to 2000°F and plunged into cold water with no deleterious effects. The intense heat of an oxyacetylene flame directed onto a plate cast from fused silica serves merely to fuse the surface, without the thermal cracking which is so typical of many ceramic materials. The opaque glassy-looking solid has three different fields of application, i.e., (1) where continuous thermal shock is required, as in the production of moulds for metal casting, the material will easily withstand temperatures in the 2100°F range ; (2) where this extreme thermal-shock resistance is not a requirement, as in the manufacture of refractory bricks for lining high-temperature furnaces, the material will stand up under temperatures in the 3000°F range ; and (3) in the case of nozzles and nose-cones for rockets, where heat and thermal shock are to be applied suddenly for short periods of time, the material will withstand temperatures in the 4500 to 5000°F range.

● *POLYMER-TYPE HARDENING SEALANT*

A new sealant, which makes it possible to dispense with press fits for retaining bearings, is a penetrating polymer which hardens only after being confined between closely fitted metal parts. The catalytic action of the metal surfaces, aided by the absence of air, is sufficient to harden the sealant into a strong heat- and acid-resistant bond. The sealant has also found applications as a liquid lock for threaded fasteners, as a sealant against porosity in welds and castings, and as a solder for certain types of joints. The polymer is intended for shear rather than tensile stresses, and a holding power up to 1000 psi can be obtained. An interesting application is in ball-bearing installations, where the usual practice is to prevent the bearing races from shifting or rotating with respect to the bearing housing or shaft by providing press fits, requiring precision tolerances on the shaft and housing bore. If the fits are too loose, the races will slip and rotate, causing fretting of the surfaces ; if they are too tight, the inside race is stretched over the shaft, and the outer race is compressed in the bore, so that the life of the bearing is shortened. In a typical case, with the use of the sealant as a filler between the outer race and housing bore, it was found that the shaft could be made 0·003 in. under the actual bore size of the bearing and still retain the bearing with a force equal to a customary interference fit of 0·0003 in. Also, when sealant-treated, the housing could be 0·0035 in. oversize and would still be equal to an interference fit. Before assembly, all parts, except the bearings, are cleaned and degreased. Care is taken to prevent any excess of sealant which might creep under the shaft seals. The assembly slips on easily without any press fits. Because it would ordinarily take 12 hr for the bond to reach maximum strength, it is heated for about an hour at 150°F.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

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THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIX No. 2 FEBRUARY, 1958

The Need for Fundamental and Wider Research on the Strength of Materials

By M. V. ZAUSTIN. (From *ASTM Bulletin, U.S.A.* No. 226, December 1957, pp. 52–61, 2 illustrations.)

When safety factors were comparatively large and when steel was the principal engineering material, ordinary test data, such as the nominal results of tension tests and a few other properties, were sufficient for satisfactory design. Now, however, the position has changed and, as indicated in this article, modern design engineers need considerably more refined, accurate, and specific data.

MODERN engineering requires not only more accurate calculations but more precise and more suitable test data, so as to enable design engineers to predict with confidence the behaviour and strength of designs. The gap between the strength of parts in service and the strength of materials determined in laboratories can no longer be bridged by large factors of safety.

In most cases the disagreement between the strength of the design elements and the strength of the specimens, made of the same material, is caused by the peculiar effect of the stress system (pattern) on the strength of materials. Regardless of whether a given stress combination is obvious, as in pressure vessels, or is hidden, as in cases of stress concentrations and residual stresses, its effect is always present. Finding the relationship between the actual strength of the design element in service and the strength of materials measured in laboratories should make a special branch of materials engineering which, when applied to metals, might be called "metal mechanics".

Metal mechanics takes into account all those features which differentiate a design element from a test specimen, and supplies data which will permit designers to make a correct estimate of the real strength of design parts, thus avoiding needlessly large or dangerously small safety factors. The ideal of modern design engineering is to leave to the margin of safety only those factors of strength which by their nature belong to the field of probability, i.e., such factors as non-uniformity of material, uncertainties of production, and unexpected behaviour of loading. However, even these factors may be treated with mathematical exactness by the theory of probability.

While materials data are based on idealized and standardized test conditions, stress analysis also suffers from simplifications and assumptions which are often far from realistic. The theory of elasticity deals with deformations and stresses in the elastic range, but entirely ignores the fact that most failures occur in the plastic range. For this reason, the stresses calculated from ordinary formulae are often not the final design stresses, since they represent the actual conditions only in the simplest cases, and often must be altered to satisfy existing conditions. Here is where the role of metal mechanics would serve as a connecting link between the strength of a part and the strength of a metal.

Modern engineering cannot be satisfied with the fundamental assumption of isotropy or perfect elasticity. It seeks to take into account such factors as directionality of mechanical properties of materials, using different moduli of elasticity in different directions, i.e., transverse and longitudinal, tensile and compressive. In some other cases, precision designing rejects Hooke's relationship and replaces it with stress-strain curves, because the proportionality between stresses and strains is only approximate in many cases. In such cases it is necessary to use tangent, secant, and reduced moduli. There are other cases in which the classical theory of elasticity should be modified to take into account "anelastic" effects, causing the deformation to be a non-linear function of applied stresses.

It can thus be seen that there is a need for having stress-strain data, not only in the elastic range but in the plastic range as well, and not only for tension but also for compression.

When stresses are not uniformly distributed, the theory of elasticity again comes into conflict with reality, owing to the fact that yield and ultimate strengths belong to the domain of plastic deformations.

If, for instance, a beam is subjected to bending by a moment which is calculated from the ordinary bending formula, using a value for the yield strength based on 0·2% permanent elongation, it will be found that permanent elongation of the outermost fibre will be less than 0·2%, probably 0·15%. To obtain a permanent deformation of 0·2%, it will be necessary to increase the load, sometimes 20% or more, the explanation being that the inner fibres of the beam, which are stretched elastically, pull back the outer fibres, which are stretched plastically and thus reduce the permanent set. A similar situation is observed in cases of torsion or in any other instances where stress gradient is present.

This is an important situation, because one of the most general principles of rational design is the use of the same criterion of strength for all design elements. In this case, the same permanent deformation used for yield strength should be used for bending. Adherence to this principle may result in a considerable saving of weight. Since, in bending and torsion cases, the magnitude of the residual deformation depends on the relationship between the elastic and plastic properties of a material, and since this relationship cannot be derived from ordinary tensile data, design engineers must have special experimental data for bending and torsion in the form of moment-deformation or stress-strain curves.

The theory of elasticity fails to answer many questions, and it is quite clear that the use of the strongest material is often far from being the correct solution in designing the strongest part. For instance, when the strongest

material is used for making bolts, it does not always result in the strongest bolts. In selecting material for a pressurized tank, an inexperienced designer may wish to take advantage of the high mechanical properties of a steel heat-treated to a high strength, without realizing that a greater ductility of the same material, treated to a lower strength, will more than compensate him with respect to strength and safety. Again, the selection of a half-hard material for a strut in compression often results in a stronger strut than would the use of a full-hard material, because of its greater degree of straightness. Parts with stress concentrations made of stronger metals are often weaker than identical parts made of weaker but more ductile material. With steels of medium strength of the order of 120,000 psi ultimate tensile strength, fatigue limits are often obtained which are almost equal—sometimes even superior to—those of steels of practically twice the static strength. There are many other facts that arise as soon as the accuracy of strength prediction is considered as a primary factor of design for minimum weight and maximum safety.

The Variable Nature of the Strength of Metals

Only a deeper detailed study of the relationship between the properties of materials and the properties of stresses will explain many phenomena and answer many questions hitherto unanswered, as well as making it possible to obtain more realistic data on the mechanical properties of materials.

Not so long ago it was believed that a material always possesses the same mechanical properties, regardless of the kind of forces applied and the character of stresses. Now, however, it is known that brittleness and ductility, for instance, are not inherent properties but only mechanical states of a metal, and that the character of stresses and the mode of their application may change the properties of a material to even a greater degree than chemical composition, heat treatment, or temperature.

The Duality of Stresses :—

No matter what the external forces are, three kinds of stresses appear together, i.e., tensile, compressive, and shear. Compressive stress as such cannot produce a fracture and, from the standpoint of strength, only tensile and shear stresses need be considered. The only difference between various forces is that they produce various ratios of tangential (shear) stress to normal (tensile) stress. This ratio is the most important characteristic of stresses and of their effect on the strength of materials. Its value for compression is 2:1, for torsion 1:1, and for tension 1:2; with pressurized vessels, plates, etc., its value is less than 1:2.

The greater the value of these ratios the " softer " is the state of stresses, i.e., the greater is the tendency of the stresses to produce a ductile deformation and ductile (shear) fracture. Thus, compression is the " softest " state of stresses. The " hardest " state of stresses occurs when the principal stresses are both tensile and equal, because the shear stresses in this case are zero.

Various Effects of the Patterns of Stresses :—

The fact that stresses may be hard or soft is important. By changing the pattern of stresses, the whole spectrum of ductility from a brittle to a plastic state can be obtained.

Cast iron, some aluminium alloys, and many other alloys that are brittle in tension (1 to 2% elongation) show a considerably ductility in torsion and become quite ductile in compression (10 to 20% elongation). Modern high-strength (low tempering-temperature) steels have small ductility in tension (2 to 3%), but are reasonably ductile in torsion. For all ductile materials, the shearing elastic limits, as determined from torsion tests, have been found to be much less than the tensile elastic limit. Steels which become brittle at low temperatures have a considerably higher temperature of transition to brittle state in tension than in torsion. In any case of stress concentration, brittle fractures occur as a result of increased normal stresses at the expense of tangential stresses. Wire drawn through dies shows a much greater ductility than when drawn without dies, because the side pressure of a die increases the tangential stress. A sharp difference has been noted between impact tests in bending and in torsion.

These examples indicate the close relationship between stress pattern, ductility, and strength of metals. They also indicate that the selection of the type of mechanical test is important for evaluation of the suitability of a metal for a given design element.

Although the final result also depends on the properties of a particular metal, it may be said that the condition for propensity to brittle fracture is when $\tau < \sigma$, and to ductile fracture when $\tau > \sigma$, where τ is the principal tangential stress, and σ the principal normal stress.

The Duality of the Resistance of Metals to Stresses:—

For the explanation of the ductile and brittle behaviour of metals, it is not sufficient to recognize the obvious effect of the dual nature of stresses. This behaviour is also a result of the dual character of the resistance of metals, i.e., the shear resistance which opposes the tangential stress, and the cohesion resistance which opposes the normal stress. Like the two types of stresses, shear and cohesive resistances also have entirely different natures. Shear resistance is the resistance of particles to slip—a plastic phenomenon. Technically speaking, the cohesive resistance is the resistance of a metal to tearing off by a normal stress—an elastic phenomenon.

The condition of propensity of a metal to brittle fracture is when $t > s$, and to ductile failure when $t < s$, where t is the shear strength of the metal, and s its cohesive strength. Any change of the pattern of stresses (τ/σ ratio) or of the properties of material (temperature, strain hardening, heat treating) produces a change in the ability of the material to resist external forces, i.e., normal and tangential stresses.

The General Condition of Ductility and Brittleness :—

The effect of stress patterns, in conjunction with the effects of the shear and cohesive strengths of materials, as a contributing factor of strength, brittleness, and ductility, is at present one of the most important problems.

When stresses increase, a failure occurs, and the type of the failure, i.e., ductile or brittle, depends on which resistance (shear or cohesive) is overcome first. In this connection, it can be shown that the character of a fracture does not depend on the absolute values of stresses and strengths, but on their ratios. This conclusion fundamentally changes the old concept that each material has only one mode of fracture. It may be safely stated that the adherence to this one-sided idea has retarded the development of a rational unified theory of strength and has been responsible for the splitting of all theories of strength into two groups, without any indication as to which group should be used in each given case. It has also retarded proper understanding of the nature of

ductility, brittleness, and the strength of materials in general.

Conditions of Brittle Fracture :—

Another important conclusion is that a brittle fracture may occur as a result of several causes. Since shear resistance is sensitive to all conditions of tests, a brittle fracture may be expected under any one of those conditions which increase the shear resistance and make it greater than the cohesive resistance. This may happen under conditions of low temperature, high speed of deformation, and change in crystalline state, such as that caused by heat treatment or strain-hardening. On the other hand, brittle fracture may be caused by reducing the tangential stress so much that the cohesive strength is overcome first by the normal stress. This is done by using biaxial and triaxial stresses.

The most urgently required data at present are on the effect of combined stresses on tensile yield strength, breaking tensile strength, hardness, etc. The need for such information will continue to exist until a method utilizing shear and cohesive strengths for any combination of stresses has been perfected.

The important problems of testing materials are not only to determine the cohesive and shearing strengths of various materials but also to investigate their properties individually. While shearing resistance obeys the laws analogous with those of fluid mechanics, i.e., it depends on the speed of deformation (flow), geometry, and temperature, cohesive strength appears to be little dependent on these factors.

These two properties of metals are the most fundamental constants of the materials because, unlike tensile strength, they are elementary. The development of methods for determination of these properties should be an important part of research at present, and it is not a simple problem where determination is needed in cases of the shear strength of brittle materials and the cohesive strength of ductile materials.

The Importance of Cohesive-Strength Data :—

It is impossible to predict the brittleness or ductility of the design elements under a full load, especially with combined stresses, without knowing the value of cohesive and shear strengths, and such predictions become very important when safety factors are small.

The strength of pressurized vessels, all kinds of plates, etc., cannot be determined with confidence without consideration of the dual nature of stresses and strength, especially in designs for ultimate (collapse) values of loads. The most important application of the duality principle is to the selection of a safe material, i.e., a material which will not become brittle under combined stresses. This point is so important that it should be introduced into the pressure-vessel codes.

It has recently been found that fatigue loading reduces cohesive strength and, therefore, high cohesive resistance is desirable for fatigue resistance. Thus, for development of metals suitable for construction of pressurized structures and of metals resistant to stress concentrations, residual stresses, and fatigue, metallurgical research should look for metals with high cohesive strength.

There is no reason why, if tangential and normal stresses in a component are known on one hand, and shear and cohesive strengths on the other, it should not be possible to determine directly the strength and safe dimensions of a design member, without referring to the unreliable theories of strength. There are many other cases where knowledge of cohesive strength is important.

Even when concerned with plastic properties of metals, cohesive strength is an important property because, when a metal is being formed or drawn, it must have sufficient strength to resist the normal stresses arising from the process. On the other hand, for machinability, cohesive strength should not be very high, in order to facilitate chip-breaking.

Stress-Strength Diagrams :—

In the stress-strength diagram (Fig. 1), *AB* and *CD* respectively represent shear yield strength and shear ultimate strength, while *MN* represents cohesive strength. With regard to the stresses, for each type of loading the ratio τ/σ of tangential to normal stress is constant and is represented by a line passing through the origin, the angle made by the line with the abscissa being determined by this ratio.

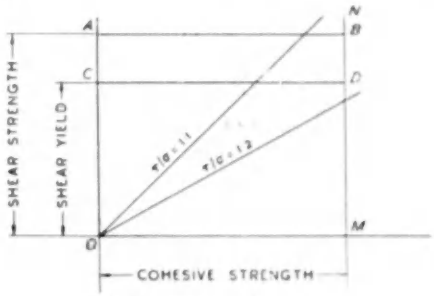

Fig. 1. **Stress-strength diagram.**

If such a diagram were supplied by manufacturers, in addition to the usual mechanical properties of metals, it would greatly facilitate the selection of materials for a given application and even the selection of the theory of strength to be used, because it permits not only prediction of the type of possible fracture but also estimation of how far a material under a given load is from the brittle state. Consider, for instance, the tension line ($\tau/\sigma = 1 : 2$), which intersects the line of cohesive resistance, indicating brittle state and brittle fracture. At the same time, the torsion line ($\tau/\sigma = 1 : 1$) intersects the shear yield line, indicating ductile yielding. Such conditions might occur in the case of a high-strength steel, tempered at a very low temperature.

In this diagram all lines are straight. This is only a first approximation, and, in reality, none of the lines will remain straight under a load. The determination of these curves for various materials and for various stress systems is one of the most important problems of modern research in the study of the behaviour and strength of materials under various types of stressing.

Since stresses change the properties of materials, stress analysis does not give a complete answer concerning the strength of a design element. It must be supplemented, if not replaced, by the strength analysis, which takes into consideration the effect of stresses on the mechanical properties of materials.

Suggestions for the Improvement of Methods of Testing Materials

Tension :—

The results of tension tests may be applied directly and with confidence only to the structural members in simple tension, but they cannot be used directly when, for

instance, there is biaxial tension. In such a case it is customary to use one of the theories of strength which is supposed to determine the magnitude of stress at which yielding begins. With regard to what theory should be used in a given case, the usual answer is that, for brittle or near-brittle materials, the so-called first and second theories should be used, and for ductile materials the others. Insofar as the question as to what materials should be called brittle or ductile is concerned, this is difficult to answer, unless shear and the cohesive strengths and stresses corresponding to them are known.

It follows that tensile-strength data from the design standpoint are only a special case of resistance of bars in tension, just as buckling strength is a special case of resistance of slender structural members to axial compression. Thus, the investigation of tensile strength must be conducted as a combination of two resistances, the value of which must be determined separately for various materials under various conditions of stressing and temperature.

Compression :—

The usual compression tests of cubic specimens made of brittle materials indicate that they break diagonally and consequently in shear. This is puzzling, since it is known that all brittle materials have greater shear than tensile resistance. However, if the top and bottom of the cubic specimen are lubricated, the fracture occurs in tension, along the planes parallel to the compressive force. This is important, because it becomes possible to determine the ratio of tangential stress to normal tensile stress, in the case of compression.

Torsion :—

Testing of materials under torsion deserves much more attention than it is usually given. Unlike tension, it produces simple stresses. The cross-section of a round bar in torsion has only shear stresses and no normal stresses. The plane under a 45-deg. angle to the axis has maximum normal stresses and no shear stresses, making a torsion fracture a distinct criterion of relative strength of the material in shear or tension (under normal stress). Because of a different τ/σ ratio in cases of torsion and tension, the shearing elastic limit is much less than that determined from tension tests. As to the yield point, the question arises as to what permanent set should be used in order to make it comparable with the yield point in tension.

Using the theory of plasticity, it can be proved that the equivalent permanent deformation for torsion is 1·5 times the permanent deformation for tension.

Shear Strength:—

Despite the fact that shear strength has been used in engineering for a long time, existing data are scarce and often unsatisfactory, probably because of the belief that shear strength is a definite fraction of tensile strength. At least one textbook on machine design gives the ratio of shear strength to tensile strength as 0·6 for all materials. In reality, this value is different for different metals and even for different states of the same metal, e.g., 0·7 for soft Monel metal and 0·56 for hard Monel metal, and 0·77 for soft nickel and 0·63 for hard nickel.

The magnitude of shear strength becomes an especially important factor in the light of duality of strength. Because of the sensitivity of shear strength to temperature, speed of deformation, stress character, and crystalline state, shear strength becomes a controlling factor of mechanical properties. Consequently, the experimental data on properties of shear strength under various conditions (speed of deformation and temperature) are needed.

Shear strength is determined in several ways, but each method requires further investigation and development. Direct single and double shear is not free from friction and bending effects. Torsion of thin tubes involves the danger of loss of stability, while torsion of solid cylindrical bars is affected by the non-uniform stress distribution. With the development of the theory of plasticity, the last method becomes more attractive. Considerable research is needed to obtain more accurate shear data for various materials and agreement among various methods of testing.

Stress Concentrations:—

There is a considerable amount of theoretical and experimental data on the weakening effect of stress concentrations, but all existing data are for the elastic range. It is well known that, in cases of ductile metals, notches have no weakening effect and in many cases have a strengthening effect. The difference is a matter of ductility, but the question arises as to which metals have this ability and which do not.

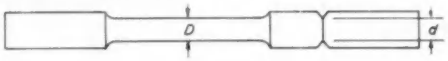

Fig. 2. **Notch specimen for static tests.**

The most reliable data on the effect of notches in static tests are obtained by means of the specimen shown in Fig. 2. The use of such a specimen is equivalent to the use of two specimens made of the same material and subjected to the same load under identical test conditions. The position of the fracture in the smooth or notched part indicates the negative or positive effect of the notch. If D is the diameter of the smooth part and d of the notch, it is possible to establish a coefficient which characterizes the effect of the notch and the propensity of the material to brittleness, i.e.,

$$\beta = \frac{\sigma_n - \sigma_s}{\sigma_s} = \frac{D^2 - d^2}{d^2} = \frac{D^2}{d^2} - 1$$

where $\sigma_n = 4F/\pi d^2$ and $6_s = 4F/\pi D^2$, F being the common maximum load that the specimen can sustain in the smooth and notched parts.

Obviously, when $\beta > 0$, the effect of the notch is positive, and the greater the value of β the more reliable is the material in design.

If the fracture takes place through the notch, in order to obtain equal strength of the notch and the smooth part it is necessary to increase the diameters of the notch. In such a case $\sigma_n < \sigma_s$ and $d > D$, i.e., the effect of the notch is negative. This method is somewhat complicated, but gives a numerical answer, although it is not free from some degree of arbitrariness, owing to the effect of shape and size. It is very easy, however, to make simple qualitative tests. It would be very desirable to add to the properties of each material its mode of fracture in the form of the above specimen, in other words, to classify the materials as having a positive or negative effect of the notch. Since the stress concentration always causes an increase of normal stresses which are resisted by the cohesive resistance, the search for the best material with optimum, resistance to stress concentrations is the search for a material with greatest cohesive resistance.

Impact :—

Single impact tests have no value for design purposes,

except for the comparison and selection of materials from the standpoint of shock and notch resistance. However, impact tests made in series, e.g., tests of the same specimens at various temperatures, permit establishing the zone of brittleness and maximum ductility for each material.

At higher temperatures, the speed effect is not sufficient to produce a cohesive fracture. Only when the temperature drops to a certain level does the shear resistance become stronger than the cohesive resistance, and the specimen breaks in a brittle manner.

As is the case in mechanical tests at present, impact tests must be conducted at elevated temperatures, as well as at room temperature. The data for elevated temperatures are necessary not only for designing structures operating at elevated temperatures but for developing technological processes, such as drop-forging or hot-rolling.

Fatigue:—

When a part is subjected to simultaneous action of constant and variable loads, the endurance limit is often determined by means of a diagram of the Goodman type. These diagrams do not agree with experimental data, because they are based on the correlation of two phenomena of differing nature, i.e., fatigue strength and tensile or yield strength. The only correct solution to this problem is the experimental determination of fatigue strength for various combinations of steady and variable loads and plotting them in the form of Smith's diagram. This kind of data is quite common in foreign literature but practically non-existent in American data books.

Another important problem in the investigation of fatigue strength of metals is the development of a method of determining endurance strength from short-time tests. In this respect, the study of mechanical hysteresis and resistance to vibrations is a promising field.

Data on fatigue strength at a small number of cycles and high stress are often required in military applications but are seldom available to the designers.

Ductility Data :—

In view of the great importance of the property of the ductility of metals, it is strange that up to the present time it has received but scant attention from materials engineers. Seldom can more data on ductility be found than elongation at fracture in 2 in. These data cannot be used in design, and their only use is in comparing the ductility of materials. This is not an accurate measure of ductility, because it depends not only on the shape of the specimen but also on gauge length. For instance, the elongation of a flat bar may be as much as 20% smaller than the elongation of a round bar. For the designer, the elongation in 100 in. has much greater value, and for a technologist the reduction of the cross-section and the elongation at " zero-length " gauge is more important. Cross-sectional reduction indicates better than elongation the forming properties of a metal. Zero-length elongation is still better in this respect.

Stress-strain curves are admittedly good indicators of ductility in simple cases. Since ductility depends on the type of stressing, and tension is rather a hard-type stress, in some cases ductility may better be determined by torsion tests. For instance, high-strength steels show very little ductility in tension but considerably more in torsion. It should be borne in mind, however, that these measures of ductility are not always comparable, and there exists a requirement for a more reliable index of ductility. If shear and cohesive strengths are available, such an index of ductility can be obtained, and the recognition of cohesive strength as a missing link in the evaluation of the ductility of metals under load may well provide a more realistic approach to the problems of heat treatment.

The cross-sectional reduction is justly considered by several authors as a better index of ductility for cold- and hot-forming operations, because it does not depend on the gauge length and characterizes the maximum deformation under conditions of test. In other respects, it has the same defect as elongation, since it does not give a complete picture of plastic flow of metal. It consists of two deformations different in nature, i.e., uniform and localized, combined in different proportions in various metals. For instance, for high-strength steels the uniform deformation is only 5 to 10% of the total ; for aluminium alloys it is 18 to 20%, and for brasses 35 to 45%. When the temperature in a specimen is lowered, the uniform deformation changes little, and in some cases even increases, whereas the localized deformation increases considerably. Again, if subjected to impact, the uniform deformation is little affected, as compared with static tests, but the localized deformation is considerably smaller. These facts, together with the fact that only the uniform deformation is utilized in technological processes, make necessary a separate investigation of uniform and localized deformations. The determination of uniform deformation, however, does not require any special tests, all that is needed being to measure, in addition to the diameter of the neck, the diameter of the straight part of the specimen.

Effects of Temperature :—

Although considerable satisfactory data on creep, i.e., the long-time effect of heat on strength and elongation at relatively low temperatures under a constant load, are available, sufficient data do not exist for certain modern requirements, e.g., a combination of high rate of loading with high rate of heating. However, although the rate of heating does not appear to be very important, the temperature itself is definitely of importance. Some tests indicate a certain increase of tensile strength with the increased rate of heating, but this increase may be ascribed to the effect of increased speed of deformation and sensitivity of the resistance of hot metals to the speed of deformation.

It might be expected that, at high temperatures, when the crystalline changes take place, the rate of heating might affect the strength of metals indirectly, by affecting, for instance, the formation of austenite in carbon steels. Recent investigations indicate that the rate of heating has no appreciable effect on the formation of austenite. This is fortunate, because high-rate heating tests may be simplified and reduced to tests of metals at high temperatures and a convenient rate of heating, as well as tests for the effect of speed of deformation at elevated temperatures. Certainly, the rate of heating is important where thermal shock is concerned, although this phenomenon is dangerous only when the material is brittle and has low thermal conductivity.

In addition to tensile strength, other mechanical properties are needed, including the modulus of elasticity, which is best determined by the vibrational method, in which longitudinal vibrations are used for determination of tensile and compressive moduli, and torsional vibration for determination of shear modulus.

In short-time heating tests, the mode of heating is important, since electric heating is practically uniform,

whereas gas heating spreads gradually from the heated surface. Strength-temperature curves are desirable, since some materials that are strongest at elevated temperatures are much more adversely affected by high temperatures than others.

Insofar as low temperatures are concerned, data on their effects are necessary in designing such equipment as refrigerating machinery and equipment for handling gases in the liquid state. Investigation of metals and alloys from the standpoint of brittleness at low temperatures is very important, but the available data about the transition point are not abundant. Other scarcely investigated problems are the strength of metals at room temperature, after they have been subjected to low temperature, and of thermal fatigue caused by alternating low and room temperatures.

Thermal Properties of Materials :—

Thermal tests include thermal conductivity, heat capacity, and thermal expansion. Heat-transfer problems cannot be solved accurately unless the heat conductivity and heat capacity as functions of temperatures are known. The value of thermal conductivity, for instance, changes by a factor of 2 or more. Unfortunately, very few data of this kind have been published, despite the fact that modern methods of instant registration of temperature permit quick and simple determinations of the thermal properties of materials.

Complete Stress-Strain Curves :—

Tensile properties of metals are best described by stress-strain curves. There are many engineering problems in which it is important to have complete stress-strain curves, which are necessary for many reasons, the most important being that their absence reduces the usefulness of the modern theory of plasticity.

Stress-strain curves are necessary in designing for maximum load (collapse load) instead of maximum stress. This method is increasingly used because of its more realistic approach to the problem of strength and safety. In many cases where this method is applicable, a considerable saving of weight is obtained. In cases of variable loading of statically indetermined structures, a stress-strain relationship is necessary for determination of the " shake-down " state of stresses, i.e., the limits of variable loading that make the structure work within the new elastic range created by the initial overloading.

Accurate stress-strain curves are necessary for determination of the usual mechanical properties of metals, such as modulus of elasticity, limits of elasticity and proportionality, yield point, ultimate strength, and breaking strength. These properties are different in torsion and must also be determined, not only for room temperature but also for low and elevated temperatures. They are necessary also for determination of tangent and secant moduli of such materials as aluminium and magnesium alloys, stainless steels, titanium, and for all metals at elevated temperatures. It often happens that a material which is the strongest at low stresses and elongations becomes the weakest at high stresses ; similarly, a material which is the strongest at room temperature becomes the weakest at high temperature. In such cases, stress-strain curves, drawn on the same diagram, clearly show the point where the difference changes its sign.

Without stress-strain curves, the development of metal-working operations and rational design of equipment for such operations is practically impossible, since stress-strain curves determine not only the limits of formability but also the elastic setback and other factors of design when permanent plastic strains are used. The shape of a stress-strain curve already gives an idea of the technological properties of a metal.

An entirely new metal can be evaluated safely if its stress-strain curve is available. In the future, the principal tools of a designer will be accurate stress-strain curves drawn with double lines, indicating minimum and maximum values. The most useful tool will be testing machines which automatically draw accurate stress-strain curves.

True Stress-Strain Curves :—

True stress-strain curves are becoming more and more important with the development of the use of the theory of plasticity. The true stress is obtained by dividing the tensile force by the cross-section at the time the stress is measured. In the area of necking, the effect of the shape of the neck has a reinforcing effect which should be calculated and deducted from the values obtained by the tests. This correction may be as much as 20%. It is necessary, because its effect is that of shape and has nothing to do with the properties of metal. True stress is widely used in the study of plastic deformations and also of elastic deformations, when they are large, as in the case of rubber. Cast iron and some cast aluminium alloys have small deformations, and the difference between the nominal and true stresses is negligible, but in the case of some stainless steels it is considerable.

True stress-deformation curves do not show the ultimate strength, but they clearly give the measure of strain-hardening. The true stress-strain curves are important when it is required to correlate tensile data with those of other forms of test, such as torsion and bending, and for the solution of the general problems of yielding and failure under conditions different from the test conditions, as in the case of combined stress conditions in structures or in hot- and cold-forming operations. The ductility of a metal and the effect of strain-hardening are more accurately determined by true stress-strain diagrams than by the use of the conventional elongation in 2 in.

Probability Distribution Data on Strength of Materials :—

Even if large safety factors are used in the determination of allowable stresses, failures occur. The reason is that the so-called minimum or guaranteed values of strength of materials are not the absolute minimum. From the standpoint of safety and reliability, it is not so much the values of minimum or average strengths that concern a design engineer but rather the scatter of the experimental results which characterize the uniformity of material. The minimum values are guaranteed in the sense that no one of the relatively small lot of specimens will fall below the specified value. If one does fail, the lot of material from which the specimens were taken will be replaced. Thus, only a curve of probability distribution of the experimental data on a large number of tests can provide a real picture of the strength of the material. Now, having another curve of probability distribution of stresses, it is possible to obtain a curve of probability distribution of safety factors, and such a curve tells what factor of safety should be selected if the percentage of failure is prescribed. This approach to the problem of safety is clear and definite, as contrasted with the ambiguous statement that a structural member is designed for a safety factor of, say, 2 or 3.

Photoelastic Investigation of a Helical Spur Gear

By E. MÖNCH and A. K. ROY. (From *Konstruktion*, Vol. 9, No. 11, November 1957, pp. 429–438, 24 illustrations.)

HELICAL gears make contact along a straight line extending obliquely from the tip towards the root of a tooth in mesh (Fig. 1). On rotation, this line of contact is displaced parallel to itself in the plane of contact, with a variation in the active length and the number of teeth in mesh. The change in torque lever arm and tooth stiffness along this line also causes variations in tooth pressure and root bending stress. The complicated geometry permits only an approximate calculation, based on the fact that the sum of the deflections of two teeth in mesh must be constant along the line of contact. An approximate determination of tooth pressure can be made experimentally from the visible width of the contact zone on teeth which have been smoked or blued before loading. The stress-freezing method, using an epoxy resin (Araldite) as a material for constructing the photoelastic model, permits a closer investigation of the contact stresses and root bending stresses under static conditions, i.e., without friction.

In helical spur gears, the general pattern of contact pressure at any point will be very nearly that made by two parallel circular cylinders with axes parallel to the line of contact and a common perpendicular to the tooth flank, the maximum root stress being very nearly in the plane of normal section. At an unloaded end-face, however, the maximum (i.e., principal) root and contact stresses must be in the plane of this end-face. Consequently, if the photoelastic sections are cut from the three-dimensional frozen model so that they represent normal sections, the principal stresses (at least at all points away from the end-faces) must fall nearly into the planes of the sections, and the maximum deviation from this plane will not exceed the value of the helix angle. It is naturally impossible to take a plane section in such a way that the tooth flanks are everywhere intersected at right angles, but the error remains very small over a large region.

EVALUATION OF THE PHOTOELASTIC PATTERN

Fig. 2 represents a section taken from the Araldite model of a helical gear, O being a free surface, e.g., at the root, shown in this case as a convex surface normal to the plane S of the section. The stress σ_3 normal to O is zero, and the principal stresses σ_1 and σ_2 in the plane of O are inclined to S. With direct viewing along the chain-dotted line perpendicular to S, the number n of fringes seen at the surface O (e.g., as in Fig. 4) of the section then indicates the magnitude of a " secondary " principal stress σ_1' parallel to S, its value being

$$\sigma_1' = \sigma_1 \cos^2\alpha + \sigma_2 \sin^2\alpha = fn/d \quad .. \quad (1)$$

where α is as shown in Fig. 2, f is the fringe value (expressed as a pressure per fringe in a section of unit thickness), and d is the thickness of the model section. If the section is now turned about the normal to O at the point considered, so that σ_3 remains zero and the ray of light L enters the section obliquely at a known angle $+\gamma$, the same equation holds, with $\alpha - \gamma$ replacing α and $d/\cos\gamma$ replacing d, and with another number n' of fringes observed. A third equation is obtained for an angle of viewing $-\gamma$, and the three equations can be solved for σ_1, σ_2, and α. In the evaluation of the maximum root bending stress of the gears here investigated, the angle α was always less than 7 deg. Since σ_1 represents the true root bending stress, and as σ_2 (the stress along the root) is much smaller, the error in assuming $\alpha = 0$ is in this case very small, so that a simple (two-dimensional) evaluation

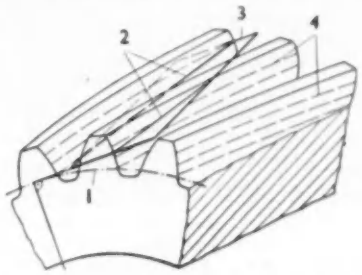

Fig. 1. **Detail of a helical gear, showing (1) the base circle, (2) the line of contact, (3) the plane of contact, and (4) tooth traces.**

by normal viewing of the highest boundary fringe order n will suffice, i.e.,

$$\sigma_1 \approx fn/d \quad .. \quad .. \quad (2)$$

If O in Fig. 2 represents an interface and σ_3 is not zero but is known to be parallel to S, as, for instance, at points directly below the centre of contact, the fringe order n in normal viewing indicates the " secondary " principal stress difference $\sigma_3 - \sigma_1'$, or

$$\sigma_3 - (\sigma_1 \cos^2\alpha + \sigma_2 \sin^2\alpha) = fn/d \quad .. \quad .. \quad (3)$$

The theory of Hertz applied to parallel circular cylinders in contact under pressure shows that the maximum principal stress difference $\sigma_3 - \sigma_1 = -0{\cdot}60\ p_0$ occurs at a point z located at a distance $0{\cdot}78a$ below the centre of contact on the surface, where p_0 is the maximum (central) contact pressure and a is the half-width of the rectangle of contact, and that at point z the stress in the direction of

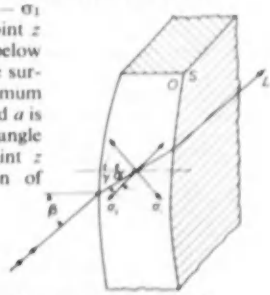

Fig. 2. **Oblique incidence of light on a section cut normal to the free surface O.**

the contact normal, i.e., parallel to S, is $\sigma_3 = -0{\cdot}788p_0$, while the stress transverse to the cylinder axes $\sigma_1 = -0{\cdot}188p_0$, and the stress parallel to the axes $\sigma_2 = -0{\cdot}488p_0$, assuming a plane state of strain with Poisson's ratio $\nu = 0{\cdot}5$, as is usual with the frozen-model technique. The half-width a, the maximum contact pressure p_0, and the load P acting on unit cylinder length are related by

$$a = 2P/\pi p_0 \quad .. \quad .. \quad .. \quad (4a)$$

$$p_0 = \sqrt{\left[\frac{P}{\pi}\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \Big/ \left(\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}\right)\right]} \quad (4b)$$

where R_1 and R_2 are the radii, E_1 and E_2 are Young's moduli, and ν_1 and ν_2 are Poisson's ratios of the two cylinders simulating the contact of the teeth in mesh. Insertion of the Hertzian stress values in eq.(3) yields, for normal incidence,

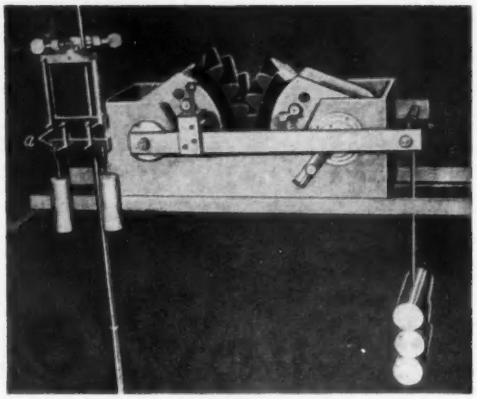

Fig. 3. Loading rig for test gears and calibration bars.

$$-0{\cdot}30p_0(1+\cos^2\alpha) = fn/d \quad .. \quad .. \quad (5)$$

With $\alpha - \gamma$ and $d/\cos\gamma$, instead of α and d, this equation also applies for oblique incidence under a known angle γ giving n' fringes at the point z; hence, p_0 and α can be calculated from two observations.

The section is mounted for normal incidence and the highest fringe order under the contact point determined visually, by Sénarmont's method, if required. The section is then turned about the contact normal and another observation for the same point is taken obliquely. The maximum angle α in the gear investigated was found to be 18 deg. According to eq. (5), the error in assuming $\alpha = 0$ is then only 4·5%, so that simplified viewing with normal incidence only and with $fn/d = -0{\cdot}30p_0$ is in this case justified. The line load P can be calculated from eq. (4b) but, since determination of the radii of curvature at the contact introduces errors, a simpler method will be satisfactory. Thus, when the highest fringe order (maximum principal stress difference) below the contact is compensated by Sénarmont's method, its point z appears black and the distance $z = 0{\cdot}78a$ from the surface can be measured microscopically on a photographic negative. As a result, a can be determined and P calculated from eq. (4a) in the form

$$P = \frac{\pi a p_0}{2} \approx -\left(\frac{\pi}{2}\right)\left(\frac{z}{0{\cdot}78}\right)\left(\frac{fn}{0{\cdot}30d}\right) \approx -6{\cdot}714fnz/d \quad (6)$$

As a check, the integral of P over the contact length, as found by evaluation of the whole series of sections, must equal the total applied tooth load.

If T is the torque to be transmitted by the proposed gears, T' the torque applied to the model, λ the scale of gear to model, and P' and σ' respectively the load per unit length and the root bending stress obtained for the model section, then, according to simple dimensional similarity, the unit load P of the actual steel gear is

$$P = P'(T/T')(1/\lambda^2) \quad .. \quad .. \quad (7a)$$

and the bending stress σ in the actual gear is

$$\sigma = \sigma'(T/T')(1/\lambda^3) \quad .. \quad .. \quad (7b)$$

However, in this instance, the deformation of the model is about twelve times that of a steel gear, so that similarity is no longer exact; in particular, the width $2a$ of the contact zone will be dissimilar. Nevertheless, it may be said that the overall bending deflection of the teeth, and hence any root stress not in the immediate vicinity of the contact point, will be proportional to the loading, independently of a, and that for small contact areas the tooth surface may be approximated to a plane infinite surface and the body of the tooth to a semi-infinite solid. The Hertzian theory then shows that, for equal values of p_0, the load P is proportional to a and the point of equal σ_3 values ($= -0{\cdot}788p_0$) is depressed proportionally with a, and therefore with P. On the whole, all the deflections are therefore approximately proportional to the loading, and simple similarity can be used without great error. Moreover, in the plane state of strain here assumed as a good approximation, the difference in Poisson's ratios for steel and for the frozen model affects only the unimportant stress normal to the plane of the section, and any possible dissimilarity in the length of contact is negligible, compared with the total length involved.

Test Procedure

The casting mould for the models consisted of a steel plate with a circular groove, into which a sheet-metal cylinder was fitted, silicone paste serving as a seal and release agent. Araldite *B* was heated to 150°C, the hardener added in a proportion of 3 parts in 10, and the mix stirred until clarified, after which it was cast in the hot mould (100°C), cured for 24 hr at 100°C, removed from the mould, and cooled at 1°C per hour. The model, now showing six cooling-stress fringes, was annealed for 72 hr at 150°C and cooled slowly as before, when it showed only one fringe in a thickness of 100 mm. The blanks were then turned and the teeth hob-milled, with a plywood plate on one side of the blank, so as to prevent chipping. When not in use, all models were stored in a desiccator.

Quarter-segments of a pair of gears were loaded, as shown in Fig. 3, by a weighted torque arm acting on the "movable" gear (left), which was mounted on deep-groove ball bearings to avoid friction and to take the thrust. The fixed gear (right) was mounted on eccentrics, so as to allow for inaccuracies in the gears and loading rig. To ensure uniform contact over the whole width, the eccentrics were so adjusted that a feeler-gauge 0·002 in. thick, inserted into the line of contact from either side of the gears, showed equal resistance against withdrawal. The meshing position was adjusted by means of set-screws supporting the fixed gear against the frame, and the torque arm was maintained horizontal by screws which positioned it with respect to the movable gear. Centre distance and tip play were chosen so as to allow for the thermal expansion of Araldite, and tooth friction was reduced by greasing with silicone paste. The calibration bars (*a*) in Fig. 3, which were cast and annealed simultaneously with the models, were loaded in pure bending, and their fringe values and Young's moduli were determined from the frozen stress pattern and the frozen deflection measured with a dial gauge.

The unloaded model and calibration rigs were heated in an oven to 150°C, and left for 24 hr, to ensure thorough heating-through of the models and the relief of any edge stresses. They were then loaded so that a satisfactory frozen fringe order would result, left for a further 3 hr, and finally cooled at 1°C per hour. The position of the sections (Figs. 6 and 7) was marked on the cold model removed from the rig. One side of the first section was end-milled, using a 120-mm cutter, and then cut to a thickness of 5 mm with a bandsaw, after which the milled side was affixed to a steel plate by means of a plastic-tape

Fig. 4 Fringes in (left to right) teeth Nos. 2, 3, and 4, for section A5 in Figs. 6 and 7.

Fig. 5. Fringes in (left to right) teeth Nos. 2, 3, and 4, for section A6 in Figs. 6 and 7.

adhesive on both sides, and the section milled down to a thickness of 3 mm. Subsequent sections were similarly obtained.

For observation under oblique incidence, the section was mounted in a special tilting rig for normal incidence, the point to be observed and its normal to the surface (or contact normal) being adjusted to coincide with a stretched wire marking the axis of rotation. The jig was immersed in a liquid of the same refractive index (1·59) as Araldite *B*, so that the fringes could be examined easily, before and after rotation through a measurable angle γ, by means of a telescope across glass walls perpendicular to the light, i.e., $\beta = \gamma$ in Fig. 2. The liquid chosen, (69·5% quinoline and 30·5% benzene by volume) did not react with the model, even after immersion for three days. The high accuracy obtained with this equipment

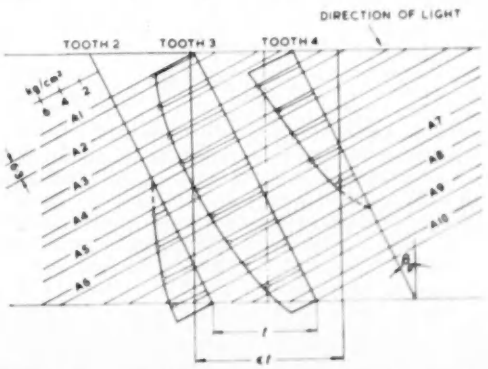

Fig. 6. Arrangement of sections and distribution of tensile root bending stresses along the contact line.

was checked by observation of vertical sections cut obliquely under known angles γ from calibration bars bent in a vertical plane, and also by recalculation of these angles from fringe observations.

Test Results

The model gears used (Figs. 4, 5, 6, and 7), each 81 mm in width and with 25 involute teeth ($\alpha = 20$ deg. normal pressure angle), had a module m of 10 mm in normal section, a helix angle β (left handed) of 27·30′, and a helix angle β_g in the contact plane of 25·40′ ($\sin \beta_g = \sin \beta \cos \alpha$). The overlap ratio (transverse) ε was 1·44, and the transverse pitch t in the contact plane was 32·76 mm ($= \pi m \cos \alpha / \cos \beta_g$), the theoretical transverse length of contact εt being 47·1 mm. The torque T' applied to the model gears was 325 kg-cm, and the total normal tooth load P_t' ($= 2T'/25m \cos \alpha$) was 27·67 kg. From calibration tests, the fringe value f of the models was 0·255 kg/cm, and Young's modulus E for the pair of gears was respectively 138 and 144 kg/cm².

Figs. 4 and 5 show the fringes in two sections under normal incidence, while Figs. 6 and 7 show the arrangement of the sections and the distribution of the root bending stress and contact line force evaluated from the series of sections, using eqs. (2) and (6), the maximum values being 5·95 kg/cm² for root bending stress, and 2·086 kg/cm for contact line force.

The refinement obtained by oblique incidence is not considered here, as it does not affect results appreciably. If the area under the curve in Fig. 7 is evaluated, the total normal tooth load P_t' is obtained, and a check gave an error of −7·5%. Consequently, assuming the distribution to be correct, the best result is probably obtained by increasing all measured values of P by 7·5%, so that the maximum contact line force becomes 2·24 kg/cm.

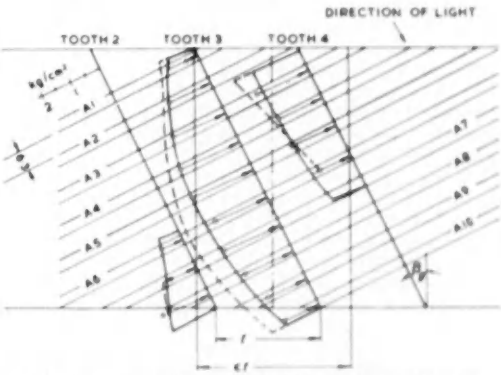

Fig. 7. Arrangement of sections and distribution of contact line force.

The distribution of the contact line force confirms the results obtained by other experimental methods, and in particular the fact that the maximum occurs near the centre and not at the sides of the gear. The chain-dotted line in Fig. 7 gives the result of an approximate analytical method and shows that the calculations exaggerate the effect of non-uniformity.

In another test, similar model gears were investigated in another meshing position, but the results obtained seemed to be somewhat faulty, probably owing to misalignment of the axes, despite all precautions. The maxima appeared near the sides and were rather higher than those obtained in the first test.

U.S.A.

Titanium-Plating Processes and Properties of Coatings

By M. E. SIBERT and M. A. STEINBERG. (From *Materials in Design Engineering*, Vol. 46, No. 6, November 1957, pp. 132–133, 2 illustrations.)

ALTHOUGH considerable research has been devoted to finding a low-cost plating method for titanium, titanium plating has not as yet reached the production stage. Nevertheless, on the basis of recent promising research, commercial use of titanium coatings appears to be imminent.

A titanium coating provides the base metal with the excellent corrosion resistance of pure titanium. Titanium coatings are smooth, essentially non-porous, and inert to a considerable number of mineral acids, alkalis, and salt solutions. For this reason they are ideally suitable for use in chemical processing equipment. Because of their poor seizing and galling characteristics, they are not, however, suitable for use on sliding surfaces where friction is present.

With the exception of aluminium chloride, unstressed titanium appears to be completely resistant to salts. Titanium has shown exceptional resistance to sea-water and has not been pitted by stagnation in crevices, under moist crystals, and under fouling growths. Similarly, titanium-plated ingot iron has shown no signs of corrosion after exposure to a 20% sodium chloride solution for three months at room temperature.

Excellent results have also been obtained with titanium-plated ingot iron exposed to acid media. Specimens tested for three months at room temperature have shown only traces of corrosion after immersion in 20% and in concentrated nitric acid, in 20% and in concentrated hydrochloric acid, and in concentrated sulphuric acid. In some cases these results differ from, and are somewhat better than, those obtained with solid titanium. For example, sulphuric acid and concentrations of hydrochloric acid above 4% attack unalloyed solid titanium quite rapidly.

To date, the mechanical and physical properties of titanium coatings have not been studied extensively, though some measurements have been made on coatings produced by electrodecomposition plating. In general, the thickness which can be obtained in one electrolysis cycle is limited to about 1·6 mils. Thickness can be built up by repeated cycling, and coatings 8 mils thick have been reported. Individual hardness measurements have been made after each of five successive electrolysis cycles during electrodecomposition plating. Hardnesses (VPN, 25-gm load) of the first to last plates were 119, 167, 340, 383, and 352, respectively. Insofar as adhesion is concerned, bar specimens have been bent through 60 deg. with no evidence of spalling or flaking of the coating. In addition, specimens have been rolled to approximately a 30 to 40% reduction without fracturing the coatings.

Theoretically, several methods are available for depositing a titanium coating, including aqueous electroplating, non-aqueous electroplating in a low-temperature electrolyte, fused-salt electrodecomposition plating, and fused-salt soluble-anode electroplating.

Because of the presence of oxygen-bearing solvents, the first two methods are incapable of producing satisfactory titanium coatings. Titanium ions have an affinity for oxygen and tend to form very strong titanium-oxygen bonds. Consequently, attempts to plate titanium from aqueous or other oxygen-bearing media invariably produce deposits of a titanium oxide or hydrated oxide rather than pure titanium.

ELECTRODECOMPOSITION PLATING

The most promising titanium coatings have so far been obtained by fused-salt electrodecomposition plating and by fused-salt soluble-anode electroplating. Inert anodes such as graphite or platinum are used in electrodecomposition plating, which deposits titanium by decomposition of an electrolytic compound. Briefly, the steps in the process can be summarized as (1) ionization of titanium salts in a suitable melt; (2) migration of titanium ions under the influence of direct current; (3) simultaneous deposition of cations at the cathode and anions at the anode; and (4) formation of gas at the anode and titanium plate at the cathode. During electrodecomposition plating the electrolyte must be replenished to maintain a fairly constant concentration.

Many of the early unsuccessful attempts at electrodecomposition plating resulted from the failure to realize the importance of using oxygen-free materials and inert atmospheres. Recently, however, satisfactory titanium coatings have been produced with a process using a titanium trichloride-sodium chloride-potassium chloride melt, and also with processes using fluoride decomposition. The fluoride-decomposition process is essentially an electrolysis of a potassium-titanium fluoride and sodium chloride salt melt which deposits titanium on a cathode. Lithium and potassium chloride salts can also be used instead of sodium chloride. However, sodium chloride has usually been selected, since it is readily available in pure anhydrous form and behaves well electrolytically.

For most work, a 15 to 17% concentration of potassium-titanium fluoride in sodium chloride has been used as the melt (fluoride concentrations of 5 to 25% have also been used successfully). This combination melts at about 1330°F and has good fluidity at the usual electrolysis temperature range of 1560 to 1740°F.

Most of the actual plating occurs during the early part of the electrolysis cycle. Plating stops after a certain point, and continued electrolysis produces a crystalline deposit around the cathode. This deposit can be washed off, however, and the cycle can be repeated to obtain a thicker plate.

Ingot iron and cold-rolled steel cathodes in the form of bars, cylinders, and truncated cones have been successfully plated. In a typical multiple electrolysis, a 0·246-in. bar was plated at 5·7 V and 95 A/dm² at 1670°F, using a 16% potassium-titanium fluoride and sodium chloride melt. After five successive plating and washing cycles, the total plate thickness on each side of the bar was 8 mils, or 1·6 mils per cycle.

Temperature has a marked effect on the process. Titanium coatings with poor continuity and bad peeling characteristics are produced below 1470°F. However, electrolysis conducted between 1470 and 1650°F always produces a diffusion bond between the titanium and the base metal, and this diffusion bond is largely responsible for the good adhesion that is obtained.

ELECTROPLATING

Despite the fact that little data has been published on the electroplating of titanium, it appears that this method of deposition is equally as promising as electrodecomposition plating. Electroplating processes using soluble anodes may employ melts which are similar to those used

in electrodecomposition plating, but the ultimate source of titanium is the anode itself. Briefly, the steps employed in electroplating consist of (1) ionization of titanium salts in a suitable melt, and (2) simultaneous formation of a titanium solution from the anode and deposition of titanium from the melt on the cathode, such that constant titanium concentration is maintained in the melt. Only the anode has to be replaced during electroplating, and process control is simpler than that required for the electrodecomposition plating process.

Extensive research has been conducted on soluble-anode processes, the most promising results being obtained with titanium trichloride melts. Successful plates have also been reported with magnesium chloride melts. Reduced halide melts have been used to plate titanium on

(*Concluded on page 70*)

RUSSIA

A New Point-Contact System for Gear Teeth

By A. N. KALUZHNIKOV. (From *Izobretatelstvo V SSSR*, No. 11, 1957, pp 26–27, 30–31, 6 illustrations.)

GEAR transmissions are one of the major factors in the development of turbo-propeller aero-engines. The reduction gear is one of the most important elements in the design of helicopters and aircraft for vertical take-off and landing, and, for this reason, improvement of gear transmissions merits the greatest attention.

In their long history of development and theoretical analysis, involute gears have reached a high degree of perfection. However, the involute tooth form no longer satisfies all the requirements facing high-power gear transmissions. The fundamental weakness of involute teeth is their inadequate contact-pressure strength, which depends mainly on the curvature of the meshing profiles. This curvature, as expressed by the Euler-Savari theorem, essentially depends on the radii of the pitch circles. Hence, if the major dimensions of the involute gears are given, it is no longer possible to vary materially the curvature of the tooth profiles for the purpose of improving their contact-pressure strength. With high-quality gear materials the direct contact stress often constitutes the limiting stress. In these circumstances it is impossible to achieve an appreciable reduction in the size of the gears and therefore in the bulk and weight of the gear transmission as a whole.

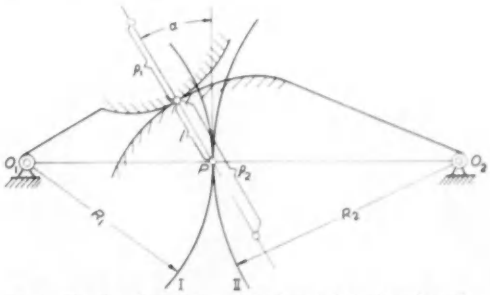

Fig. 1. Notation of quantities entering into the Euler-Savari equation.

Gear transmissions with involute teeth, like all gears with line contact, are highly sensitive to errors in the alignment of the gear axes. Angular alignment errors resulting from machining or assembly cause a non-uniform distribution of the load along the face width of the tooth. Pitch and profile errors cause additional dynamic loads, and hence the actual stresses in the teeth are considerably higher than those computed from the average tangential forces. Deformations of the supports, the shafts, and the teeth under load also cause a non-uniform distribution of loads along the face width and thus have a detrimental effect on the operation of gear transmissions.

Many examples show that gears with line contact which, in theory, are meshing correctly do not operate satisfactorily in practice. When designing gear-wheels, it is necessary to make extensive use of so-called " barrelled " teeth for spur-gears and of teeth with a limited zone of contact in bevel and hypoid transmissions. These types of teeth operate with a point contact, but this point contact is derived from a line contact and thus constitutes, in a sense, a " distorted " or " degenerated " line engagement.

In the analysis of the contact-pressure strength of gear teeth, the radii of curvature of meshing profiles in the transverse-plane cross-section play a large part. These radii of curvature cannot, as is well known, be arbitrary. The relation between the radii of curvature of meshing profiles, the radii of the pitch circles, the pressure angle, and the distance of the point of contact from the pitch point is expressed by the Euler-Savari equation, i.e.,

$$\left(\frac{1}{\rho_1 + l} + \frac{1}{\rho_2 - l}\right)\sin\alpha = \frac{1}{R_1} + \frac{1}{R_2}$$

The notation of the quantities which enter into this equation is illustrated in Fig. 1. When the point of contact coincides with the pitch point, the Euler-Savari equation assumes the form

$$\frac{1}{\rho_1} + \frac{1}{\rho_2} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)\frac{1}{\sin\alpha}$$

The left-hand part of this expression constitutes the so-called effective curvature, which is the basic geometrical factor affecting the magnitude of contact compression stresses.

Substituting in the Hertz formula (expressing the compression stress in bodies under direct contact pressure) the expression for the effective curvature so obtained, the maximum value of the compression stress is given by

$$\sigma = 0{\cdot}418\sqrt{\frac{P_n E}{b}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)\frac{1}{\sin\alpha}}$$

where P_n is the tangential force and b the face width.

The application of the Euler-Savari equation to the case of the involute tooth profile, shows that, with internal gears, in which a convex profile rolls along a concave profile, the magnitude of the effective curvature is considerably smaller than in external gears, where one convex profile rolls along another convex profile. The magnitude of the effective curvature in internal gears diminishes with a decreasing difference between the radii of curvature of the meshing profiles.

Fig. 2 shows a case of external gear engagement in which, however, as with internal involute gears, a convex profile rolls over a concave profile. The radii of curva-

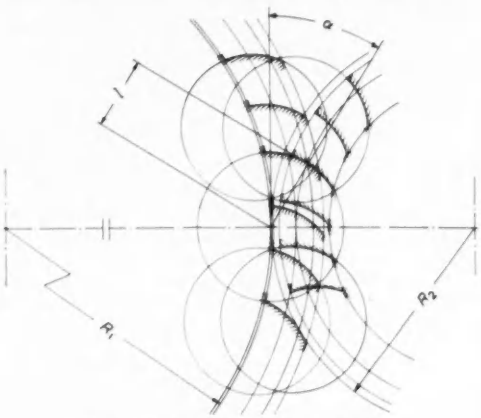

Fig. 2. Diagram of external gear-wheel contact.

ture of the meshing profiles are equal, and these profiles are circular arcs so situated that, at the instant of contact, the common centre of the identical circular arcs is at the pitch point. Once again, this a line contact, and the effective curvature is zero. Consequently, its reciprocal, i.e., the effective radius of curvature, becomes infinite. The engagement so illustrated serves as the basis of a new system of gear meshing, invented by Novikov, and already subjected to a limited amount of practical testing. Gear-wheels made in accordance with these new principles can transmit a torque up to four times greater than involute gears of the same size designed for the same contact-pressure stress, the same friction losses, and other identical conditions. A typical pair of gears made on this principle is shown in Fig. 3.

The new system is distinguished by low sensitivity to machining inaccuracies and to deformation in service, and permissible peripheral speeds can be much higher than those in conventional gear transmissions. In addition, it is applicable to gear transmissions with parallel or intersecting or non-parallel and non-intersecting axes and can be applied to external and internal gears alike, or it can be used for gears with a constant or a variable ratio.

The essence of the system is that the path of contact is prescribed as a straight line or a smooth curve passing in the immediate vicinity of the instantaneous axis of relative rolling and sliding, and this line or curve is confined in the space associated with the axes of rotation of the gear-wheels. The motion of the point of contact along the path contact is assumed to take place at a constant or smoothly varying velocity, the moving point of contact describing contact lines in the spaces associated with each of the rotating gear-wheels.

A large number of surfaces of a certain type can be visualized to contain these contact lines. These surfaces can be the conjugate working surfaces of the teeth, provided that they satisfy the following conditions :—

(1) They must have a common normal at each momentary location of the point of contact.
(2) The basic theorem of tooth engagement must be fulfilled.
(3) The curvatures of these surfaces must satisfy the prescribed gear ratio.
(4) Within the limits of their working zone, there must be no interference between these surfaces.

In planes normal to the instantaneous axis of the relative rolling and sliding motion, which pass through the momentary location of the point of contact, circular arcs can be struck about centres located on the straight line passing through the point of contact and the instantaneous axis, and located furthermore in the immediate vicinity of this axis. These circular arcs can be taken as the tooth profiles, and the continuous sequence of profiles for all locations of the point of contact forms the conjugate tooth surfaces. In this way, the working surface of one gear tooth is convex and that of the other is concave, in the direction normal to the instantaneous axis, as shown in Fig. 4, in which P is the point of intersection between the instantaneous axis of relative rolling and sliding and the profile plane perpendicular to the instantaneous axis, O_1 and O_2 are the points of intersection between the plane of the profiles with the axes of the gear-wheels, and A is the point of contact. PA is the pressure line (path of contact), or, more accurately, the common normal to the profiles at point A. DAD is the circular arc with its centre at P, constituting the limiting case of the tooth profiles when they coincide with one another, while curves BAB, of an arbitrary smooth shape inside arc DAD (i.e., re-entering the " body " of the tooth of one of the gear-wheels) are situated in the immediate vicinity of this arc and constitute the profiles of the teeth of one of the wheels. Similarly, curves CAC, located outside arc DAD, constitute the tooth profiles of the other wheel.

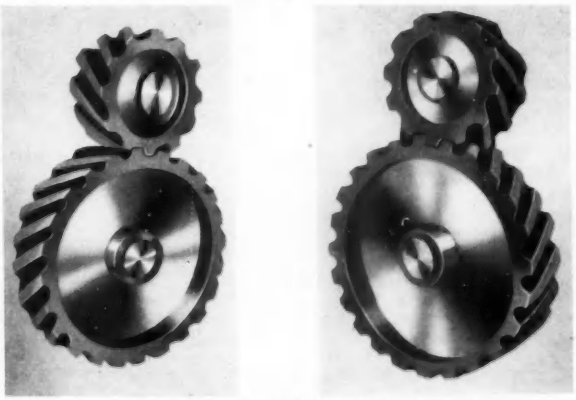

Fig. 3. Views of a typical Novikov-type gear pair.

The radii of the tooth profiles could be of the same magnitude, equal to the distance between the point of contact and the instantaneous axis. In this case, point contact degenerates into another form of line contact. However, in order to achieve this, a rather high degree of accuracy is required, and the centre distance must remain absolutely constant, neither condition being attainable in practice. In designing gear teeth, preference must be given to point contact with a small difference between the profile radii. It should be borne in mind that, both in manufacture and during the running-in

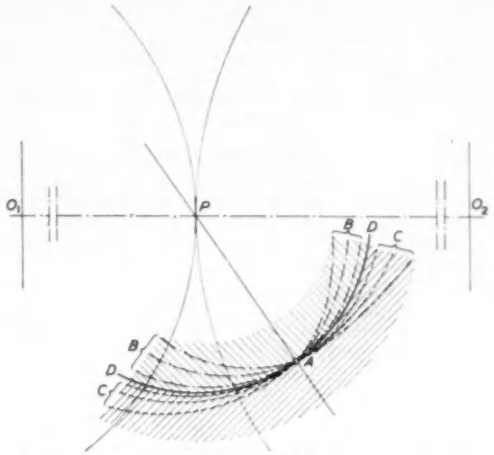

Fig. 4. Sequence of profiles for all locations of the contact point forming conjugate gear surfaces.

period, point contact will remain point contact only in theory, as in practice it will gradually approach line contact.

The tooth profiles could have a different shape from the circular arc. However, profiles of a different form which always pass through the point of contact must remain inside the above-mentioned circular arc, whose centre is located on the instantaneous axis ; in other words, they must re-enter the " body " of the teeth, as shown in Fig. 4.

In order to ensure low friction losses and minimum wear, the path of contact should be near the instantaneous axis. In selecting a law of motion for the point of contact, a favourable angle must be maintained between the common normal (along which the force between the teeth acts) and the axes of the wheels.

The tooth thickness and pitch are decided by the necessary tooth strength in bending and shear. The thickness of the gear rim and the face width of the teeth must be so related to the pitch that the prescribed overlap factor is achieved. Gear transmissions may have single-point contact, i.e., a single pair of teeth only may carry the whole load transmitted, or transmissions can be designed with multi-point contact, where several pairs of teeth are in contact simultaneously.

In the case of gear transmissions with parallel axes it is most convenient, on account of design and production considerations, to select a path of contact in the shape of a straight line parallel to the axes of the wheels, and to assume a uniform motion of the point of contact. In doing so, the radii of the tooth profiles in all planes normal to the axes will be the same. The working profile surfaces of the teeth will then have the shape of exact helicoidal surfaces.

The manufacture of such teeth is possible on all modern gear-cutting machines, but special tools are required. In order to balance axial pressure on the bearings, gear-wheels of double-helical configuration can be chosen.

Comparative tests were run with involute-gear transmissions and with gears made on the new principle, in both cases of the same material and size. These tests, which have not yet been completed, lead to the preliminary conclusion that the new transmissions have a torque capacity of from three to four times that of the conventional type.

SWITZERLAND

Cathodic Protection in Industrial Refrigerating Plant

By L. Piatti and H. Bourquin. (From *Sulzer Technische Rundschau*, Vol. 39, No. 4, 1957, pp. 31–37, 5 illustrations.)

Cathodic protection of metals depends on neutralization of the electric current causing corrosion, and this can be achieved in two ways, i.e.,

(1) *Sacrificial protection*, in which an anode of zinc or magnesium is introduced into the electrolytic medium, the metal to be protected then acting as a cathode, while the expendable anode corrodes in its place.

(2) *Cathodic protection by external current*, in which a negative voltage from a d.c. source is applied to the metal to be protected, preventing the development of anodic points on its surface.

It is known that remarkable results can be obtained by protecting with an external current metal parts in contact with brines in refrigerating plant. However, the objection has been raised that sufficient protection is already obtainable in most cases by the addition of chromates to the brine. The effectiveness of this latter method of protection has been confirmed by tests at the Sulzer laboratories, which showed that, by adding 0·3% calcium chromate to a calcium chloride brine, the attack on an unalloyed steel can be reduced by a factor of ten. This method was then applied to equipment for the chemical industry, when it was found that after an extensive period there was no rust deposition present on the steel tubes and also no discoloration of the brine.

Chromates, however, cannot be employed everywhere, as human skin is sensitive to chromate solutions and may develop eczema. Consequently, in processing plant for foods and beverages, the use of chromates is not advisable, and cathodic protection is always preferable.

The cooling brines used in refrigerating plant are usually fairly concentrated solutions of calcium chloride or sodium chloride, which have a strong electrolytic action and are particularly corrosive at low pH-values and with high oxygen content. Moreover, the salts contained in brines are also dangerous, because they can form free acids through hydrolysis, ammonium or magnesium chlorides being particularly active because of this tendency. Another decisive factor is their ability to dissolve corrosion products. Chloride solutions dissolve anodic products, e.g., ferrous chloride, and cathodic products, e.g., sodium hydroxide, with the result that the rate of corrosion is increased.

The corroding action of a brine is due to its ability to absorb iron in the form of ions, its reacting capacity being a function of its pH-value, concentration, and temperature. The influence of oxygen content is partic-

ularly important. By oxidation of the hydrogen inhibiting cathodic corrosion, the oxygen acts as a depolarizer and converts the dissolved iron into a hydroxide, which settles out as rust and thus enables the brine to absorb further amounts of iron. Fig. 1, based on the investigations of Hache,* shows the dependence of the corrosion capacity of a sodium chloride brine on its concentration and its relation to oxygen content.

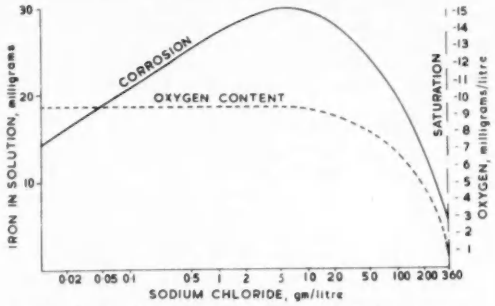

Fig. 1. **Attack of a sodium chloride brine on rolled-steel strip as a function of concentration and oxygen content at 24° C.**

Particularly intensive attack, resulting sometimes in pitting corrosion, is obtained when leaking ammonia from a corroded evaporator system is added to the brine, owing to hydrolysis of the ammonium chloride formed. Welded joints are particularly sensitive, because of possible pores, inclusions, and structural inhomogeneities. With an increasing number of leakage points, severe damage to brine-covered metal parts can be expected when the ammonia content reaches 100 grams per 100 litres. A good coating may reduce somewhat the destruction of material, but will not prevent it completely.

The present practice at Sulzer is therefore to employ cathodic protection for the evaporators of ammonia refrigerating plant. Initially, the method of sacrificial protection was tried, using zinc anodes, but results were not always satisfactory, as measurements sometimes showed values which did not attain the minimum of —0·85 V accepted for protection of iron or steel against corrosion. The problem with sacrificial anodes is to arrange them in such a way as to obtain a uniform flow of current to all exposed surfaces. In many cases, this is not possible, owing to the space available and the geometry of the installation. Consequently, it was decided to use the method involving cathodic protection by external current.

A typical case where external current has given the required protection is that of an ice generator in a brewery. This comprised a steel tank of 8 × 4 × 2 metres, with a centrally arranged ammonia-type vertical-tube evaporator, the ice cans on both sides passing slowly through deep-freeze sodium chloride brine.

As is only to be expected, the arrangement of the anodes gave rise to a number of problems in field distribution. In this connection, it should be remembered that it is not easy to obtain a satisfactory arrangement of electrodes when the latter are close together. In compact arrangements, the lines of current in the electrolyte frequently show an asymmetric pattern, with most of the current going to the components nearest the anode, and this partial short-circuiting reduces the effectiveness of the protective system.

In this particular ice generator, the anodes (graphite tubes, 125 mm in diameter and 2 m in length) could only be fitted in the four corners of the tank, because of the ice cans. The current was taken from a 6- or 12-V storage battery, subsequently replaced by a rectifier, but, even with a considerable amount of current, it was not found possible to reduce the potential of the sheet-metal walls of the tank to a value below —0·85 V, though this was fairly easily obtained on the evaporator. It was therefore decided to make no special attempt to protect the tank walls ; this was permissible, as the evaporator was the most vulnerable unit. The tank was treated in a fairly simple manner by applying a suitable coating. This, however, would have been far more difficult to apply to the evaporator system without impairing the flow of heat and reducing its operating efficiency. By restricting the cathodic protection to the evaporator system itself, and using a total current of only 9 A, the protective potential reached a permanent value not exceeding —1·4 V at any point. As the surface area of the evaporators was 223 m², the desired results were thus achieved with a current density of 40 mA/m².

The type of surface protection for refrigerating plant also requires careful selection. It appears that the protective action of a coat of paint originates in the thin boundary layer adhering to the metal. The resistance of this layer is about 100 times that of the other layers of the coating, and can attain some millions of ohms. The coating should be as far as possible free from pores, as well as electrically non-conductive, enabling it to act as an insulator, with the same effect as an increased distance between electrodes.

When cathodic protection is used in parts of a plant, the choice of a suitable coating becomes more difficult. Owing to the protective current, hydrogen ions from the electrolyte are discharged on the metal surface. However, the hydrogen becomes oxidized only to a limited extent, particularly if the current intensity is greater than that effectively required, leading to the formation of gas bubbles. Free alkali, which has a detrimental effect on many types of coatings, can then accumulate at the cathodes.

Electrically non-conductive coatings are employed chiefly for reasons of economy. Organic coatings reduce the surface area requiring cathodic protection, and hence also current consumption, as they require protection only at weak points, e.g., in porous areas. However, in refrigerating plant, the current employed is fairly small, and the cost of the additional current consumption can be regarded as insignificant.

To ensure effective protection of all exposed surfaces, the use of more than the minimum required current can be recommended, although this may cause damage to coatings. However, after various tests, Sulzer have been able to find a coating material suitably resistant to brines and electric current.

A remarkable point is that the amount of current required for constant protection decreases in the course of time. It is known that, with electrolytes containing alkaline-earth salts, the formation of layers of lime on bright metal sections causes such a decrease in current. However, investigations carried out in conjunction with the present work have shown that, with an installation operating with fresh water, the cathode potential relative to water, with zero current, was not —0·5 V, as would be expected from the neutral condition of the system, but between —0·9 and —1·0 V, while in several applications it was observed that current consumption decreased after fairly long periods of operation.

*A. HACHE. *Revue Métallurgie*, Vol. 53, 1956, page 76.

Velocity-Displacement Transfer Mechanism with Programmed Cams

By J. B. Reswick and J. Wright. (From *Control Engineering*, Vol. 4, No. 12, December 1957, pp. 76–79, 12 illustrations.)

Many machine-tool processes require automatic rapid transfer of heavy workpieces between stations, and, as transfer rates increase to reduce transfer time, the forces for accelerating and decelerating the mass being moved must also become greater. Many configurations of mechanical and hydro-mechanical transfer devices can control the accelerations and velocities in the transfer cycle, but they frequently use open-ended on-off control and require hydraulic buffering chambers. Moreover, it is often difficult to design mechanical linkages which yield the ideal characteristics of zero acceleration at the beginning and end of transfer.

The effects of oscillation and noise, and transfer-design drawbacks can be reduced by close control of the forces developed in moving a mass a given distance in a given time. Experiments have been carried out to develop a velocity-displacement transfer mechanism that could give continuous predetermined control of velocity and acceleration over the entire length of transfer. The mechanism contains a cam programme of desired velocity *versus* mass displacement. The programme acts as the input to a closed-loop system, which thus seeks continuously to reduce the error between the programmed velocity and the actual velocity of the moving mass. By comparing the output velocity with the command velocity, the system produces an acceleration (or deceleration) which is a function of the velocity error. Careful consideration of design parameters, together with a flow-control valve with a fast response, assures a minimum velocity error and adherence to the acceleration and deceleration programmed on the cam.

The major components of the system are shown in Fig. 1, in which a four-way directional valve (1) directs a constant-pressure hydraulic supply to a fluid motor (2), which drives a pinion-and-rack combination (3). The rack directly drives the mass (5), which is mounted on rollers and supported by parallel bars and can move between end-stops (6). The flow out of the fluid motor is directed back to the four-way valve (1) and thence to a flow-control valve (9), after which the fluid is returned via line (7) to a tank.

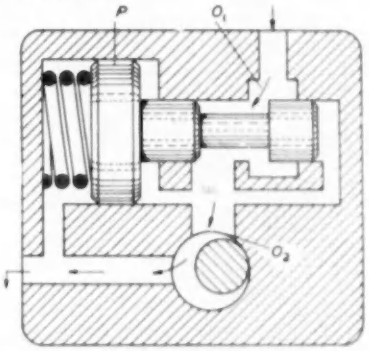

Fig. 2. Arrangement of the flow-control valve.

The loop is closed through the programmed velocity-displacement cam (4). This cam moves with the mass, and the cam-slide (8) feeds back to the outlet orifice O_2 of the flow-control valve (9) an angular position as a function of mass displacement. Orifice O_2 meters the flow out of the hydraulic circuit and hence controls the velocity of the moving mass ; consequently, the actual position of the mass at any time during the cycle determines what the mass velocity should be at that time.

The flow delivered by the fluid motor (2) to the flow-control valve (9) through the inlet orifice O_1 is compared continuously with the flow demanded by the angular

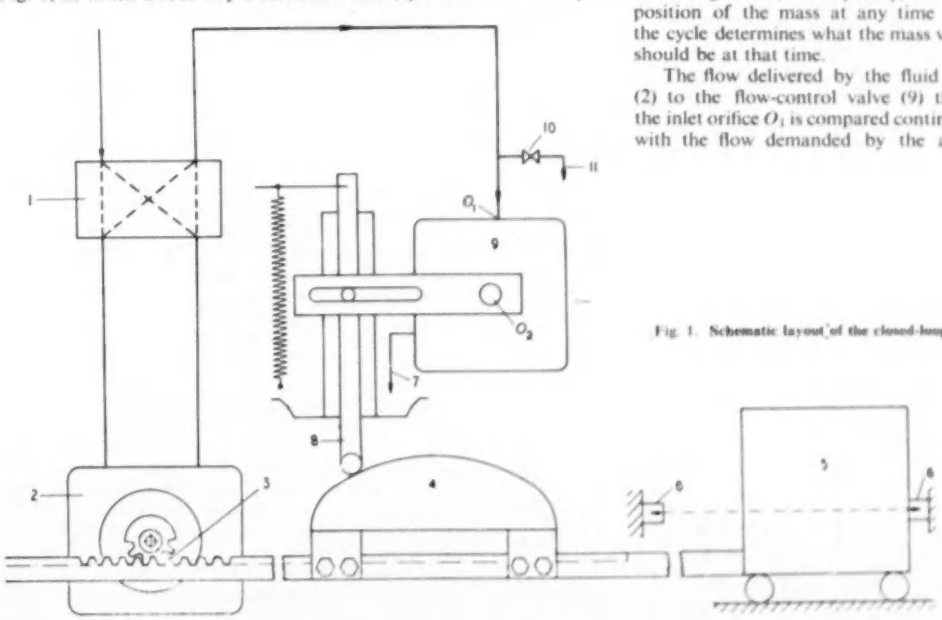

Fig. 1. Schematic layout of the closed-loop system.

position of the outlet orifice O_2. The arrangement of the flow-control valve is shown in Fig. 2, in which a compensating piston *P* continually adjusts the area of orifice O_1, keeping the flow error small and thus causing a rate of change of inlet flow (acceleration), which is a function of this error.

Orifice O_2 is completely closed at the beginning and end of each cycle, and can be opened only by a small increment of displacement. However, once the mass has been given even a minute displacement, hydraulic flow in the system is self-regulating, according to the programme on the cam (4). As shown in Fig. 1, this initial displacement is accomplished by a by-pass (10) in a line (11) around the flow-control valve to the tank. The resulting flow, controlled by adjustment of the needle-valve in the by-pass line, causes the fluid motor (2) to rotate slightly and to move the mass (5) at the very commencement of transfer motion. In actual production models of the transfer mechanism, the by-pass would also permit full system pressure to hold the mass firmly against the end-stops (6) while mechanical fingers load and unload the workpieces.

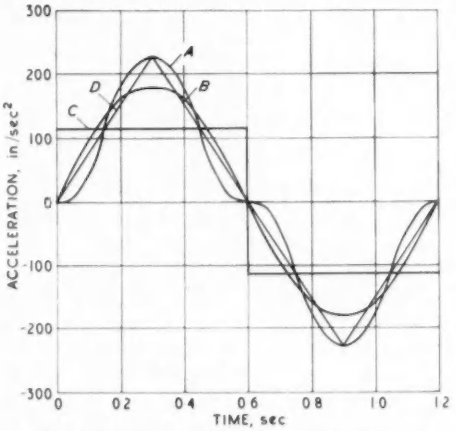

Fig. 3. Acceleration-time curves for four cam programmes.

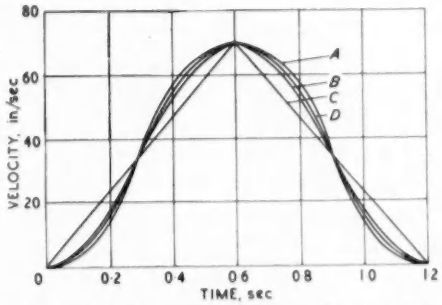

Fig. 4. Velocity-time curves for the four acceleration functions shown in Fig. 3.

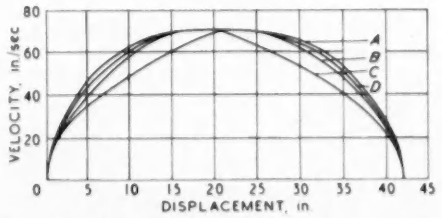

Fig. 5. Velocity-displacement curves for deriving the cam profiles.

In designing cams for this mechanism, the ideal theoretical shapes for four particular acceleration functions were considered. These are shown in Figs. 3, 4, and 5, in which in each case curve *A* is a cosine acceleration with the axes displaced, so that the function has a zero derivative (zero acceleration or force at the start); curve *B* is a pure sine acceleration, curve *C* is a constant-acceleration square wave, and curve *D* is a constant-slope acceleration. With each of these functions, the same transfer distance is traversed in the same time.

Fig. 3 shows the four acceleration-time curves, and Fig. 4 their corresponding velocity-time curves. The curves in Fig. 4 are converted to the velocity-displacement cam profiles shown in Fig. 5. The sine-wave and square-wave acceleration curves are relatively easy to generate in either exact or approximate forms, using the usual mechanical linkages, but mechanical generation of the cosine and triangular acceleration function curves (curves *A* and *D*) are more difficult. Curves *A* and *C* represent the extremes of accelerations which can occur at the beginning and end of the transfer cycle, with zero acceleration for the cosine function and maximum acceleration for the square-wave function. For these reasons, curves *A* and *C* were chosen for experimental cam profiles, although, with the closed-loop system and the velocity-displacement cam, all wave forms are equally easy to generate.

The actual layout of the physical cam requires conversion of the command velocity to its equivalent angular position of the variable orifice, and relating this angle to the corresponding value of displacement. This may involve non-linear relationships between angular position, flow, and velocity, which can be accounted for graphically. In the present case, however, the relationships are essentially linear, making the conversion straightforward.

The particular flow-control valve used in the tests was limited to a maximum flow of 57·8 cu in./sec, and this flow through the fluid motor limited the maximum velocity of the mass to 70 in./sec. The transfer distance was established at 42 in. Cams representing the extremes of the acceleration function (curves *A* and *C* in Fig. 3) were constructed, and simultaneous recordings were made of the velocity of the moving mass and of the vibration and shock on the structure. The velocity was measured by driving a d.c. generator attached to the mass through a rack-and-pinion, while vibration and shock were measured with strain-gauges.

Comparisons of the test results obtained from these recordings for the cosine velocity function and the square-wave velocity function, compared with the ideal functions shown in Fig. 3, have demonstrated that the experimental velocity-displacement transfer mechanism is capable of reproducing faithfully enough either extreme of the acceleration functions on a moving mass. Incidentally, it should be noted that the recordings showed a relative smoothness of the shock pattern on the structure for the cosine function and a noticeable peak at the end of the transfer motion in the shock pattern for the square-wave function. As was to be expected, the cosine acceleration function appears to be much smoother in its action than the square-wave constant-acceleration function.

Developments in Steam Power Generation in Eastern Europe

By Eugene Gros

This article deals with recent developments in the field of steam power generation in Russia, Czechoslovakia, and Hungary, and is based on information released originally at the Fifth World Power Conference, held in Vienna in 1956. This information has been supplemented and brought up to date on the basis of data subsequently received by the author.

The Russian development is concerned with two-stage evaporation, and that from Czechoslovakia with the control of steam temperature by injection of condensate produced from saturated steam, while the Hungarian development is concerned with improved air-cooled condenser plant.

Two-Stage Evaporation

A Russian development reported by Panassenko and Najow[1] relates to the use of two-stage evaporation in boiler plant, which has so far been relatively little employed in the West. Development work on two-stage evaporation commenced in the 1930's, and its use has increased considerably in Russia for boilers fed by chemically treated feedwater, e.g., in district-heating stations, where the condensate is not returned from the heating mains. In such stations, when using single-stage evaporation, it is necessary to blow-down up to 10% of the water fed into the boiler, adversely affecting the water and the thermal conditions of the station.

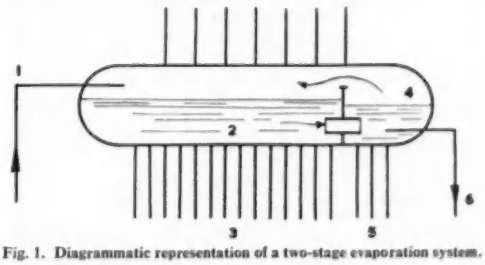

Fig. 1. Diagrammatic representation of a two-stage evaporation system.

Two-stage evaporation, on the other hand, permits high concentration of the boiler water without deterioration of steam purity. An essential feature is that steam production is effected in two stages, as can be seen in Fig. 1, in which both evaporation stages have a common drum which is subdivided by means of a partition into two parts (2) and (4) of unequal size. Feedwater is introduced via a pipe (1) into the larger part (2) of the drum, to which are connected the downcomers and risers of most of the evaporation surfaces (3). In this first evaporation stage the feedwater is largely converted into steam, and the remaining (partly concentrated) water flows into the second evaporation section (4). The water flowing into this section represents the blow-down of the first evaporation stage and forms the feedwater for the second section, where the second stage of evaporation takes place and where it becomes highly concentrated. From this second stage the blow-down passes through pipe (6). The design of the partition must be such that the flow of water is possible only in one direction, so that the water with a high concentration of salts cannot return to the first stage.

The evaporation surfaces of the first stage contain boiler water with low salt concentrations, so that high evaporation rates can be used. Consequently, the evaporation surfaces (3) of the first stage can be located in the area of high furnace temperature, whereas the evaporation surfaces (5) of the second stage must be located in the area of lower flue-gas temperatures.

Two-stage evaporation also permits a reduction in the dimensions of the drum. Since the separation of steam from the water is effected in separate sections of the drum, it is possible to obtain considerably higher rates of evaporation in the first stage, in which the concentration of salts in the boiler water is low, without adversely affecting steam purity. On the other hand, in the second evaporation stage, only a small part of the steam is generated, so that it can be dimensioned more generously without increasing the size of the drum. The conditions are particularly favourable in the case where the steam in the drum is evaporated only from the first stage, whilst steam from the second stage passes through a series of external cyclone separators, whence it flows into the drum. The quality of the steam can be further improved by washing it in the boiler water of the first stage of evaporation, which, as mentioned, has a low concentration of salts.

Subdivision of the evaporation into two stages also facilitates the chemical operating conditions of the boiler. It is, for instance, possible to alkalize the water by means of trisodium phosphate solely in the second stage of evaporation, while operating with non-alkalized boiler water in the first stage[2].

Two-stage evaporation is most favourable in boilers with natural circulation. In boilers with forced circulation it is less suitable, since two circulating pumps (one for each stage) would be required.

An extension of the treatment of the make-up water is demineralization, in which the cations and anions are captured chemically prior to its introduction into the boiler. In this case, two-stage evaporation loses its importance as a means of reducing the blow-down of the boiler, since in this case the required blow-down of the boiler is very low, even if condensate is not returned. This does not, however, mean that two-stage evaporation becomes superfluous, as, even here, a low salt content in the steam of the first evaporation stage is an advantage and yields, an improvement in steam purity. In this case, two-stage evaporation permits, for instance, a simple and convenient method of preventing the passage of silica from the boiler water into the steam. Thus, two-stage evaporation is conducive to the production of high-purity steam, mainly for pressures above 150 atm, in cases where the steam is able to dissolve considerable quantities of salts.

When designing boilers with two-stage evaporation, the correct subdivision of the boiler output of the first and second evaporation stages is of great importance. The steam output of the second stage is made very small, usually 5 to 10% of the total steam output of the boiler. A low steam output from the second evaporation stage permits the production of most of the steam from water with a low salt concentration from the first stage of evaporation[3].

7—E.D.

Control of Steam Temperature by Injection of Condensate Produced from Saturated Steam

In Europe, as well as in America, steam temperature is frequently controlled by means of injection, the advantage of this simple control system being a very low loss of pressure of the steam in the injector—a feature of particular importance in the case of high-pressure boilers. However, great attention must be paid to maintaining a high purity of the injected condensate, in order to avoid contamination by salts of the steam during the injection process.

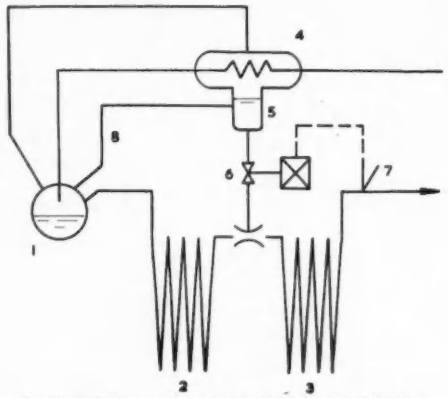

Fig. 2. **Control of steam temperature by injection of high-pressure condensate produced from saturated steam.**

In this connection, a method of controlling steam temperature by injection of a high-pressure condensate produced from saturated steam has been developed in Czechoslovakia, and is reported to have been used successfully on a number of large boilers since 1952. The essential feature of this system[4] is that the condensate required for injection is produced in the boiler itself at the full pressure of the saturated steam. Part of the saturated steam produced is condensed by the feedwater in a surface-type heat exchanger, which can be arranged at the water side either behind the economizer or at the boilers, with an evaporative economizer between the first and second economizer stages. A diagrammatic representation of this temperature regulation system is shown in Fig. 2, in which part of the saturated steam is fed from the drum (1) into the condensing feedwater heater (4). The condensate accumulates in the reservoir (5), and is then fed through the injection control valve (6) into the injector. The degree of opening of the valve is controlled by a thermostat (7), in accordance with the final temperature of the superheated steam after it has passed through primary and secondary superheaters (2) and (3).

The quantity of condensate produced is directly proportional to the quantity of feedwater fed into the boiler, so that, in addition to ensuring that the production of condensate is somewhat larger than the maximum quantity required for injection, it is necessary to provide a certain reserve for covering occasional differences between production and consumption of condensate. As a result, the pipe through which the condensate flows to the injector must be of large diameter, serving simultaneously as an additional condensate reservoir for covering requirements for injection water during periods when the quantity of feedwater supplied to the boiler is small. The excess condensate produced is returned by means of pipe (8) to the boiler drum (1).

The advantage of this system of temperature control is that, in addition to ensuring identical purity of superheated steam and injected condensate (since both are produced from the same saturated steam), regulation anticipates temperature changes in the superheated steam, because injection is effected by a pressure which is proportional to the pressure loss of the steam in the primary superheater (2), which is located in front of the injection point, since the pressure in the condenser is equal to the pressure of the saturated steam in the drum.

The entire control process, in the case of a sudden increase in boiler output, can be assumed to consist of two separate processes. Owing to the increase in pressure loss in the superheater, caused by a sudden increase in boiler ouput, the quantity of condensate injected will immediately increase in direct proportion to the increase in boiler output, without any change in the setting of the injection control valve ; as a result, the quantity injected will be varied and the possible temperature deviation of the superheated steam will become smaller. Only after a certain time lag will the change in output manifest itself with the response of the thermostat, which, by means of suitable controls, will effect the necessary correction in the quantity of condensate injected by changing the setting of the injection control valve to the required value. The regulator, which is controlled by the temperature of the superheated steam, merely provides additional regulation of the steam temperature which has already been regulated by a change in the injection pressure.

Recently, information has been published on proposals to produce, mainly for small stoker-type boilers, the injection condensate in condensers cooled by the combustion air of the boiler. Using such a system, the conventional air preheater could be dispensed with.

Air-Cooled Condenser Plant

A new method of condensation by air cooling has been developed in Hungary by Heller and Forgó[5] and

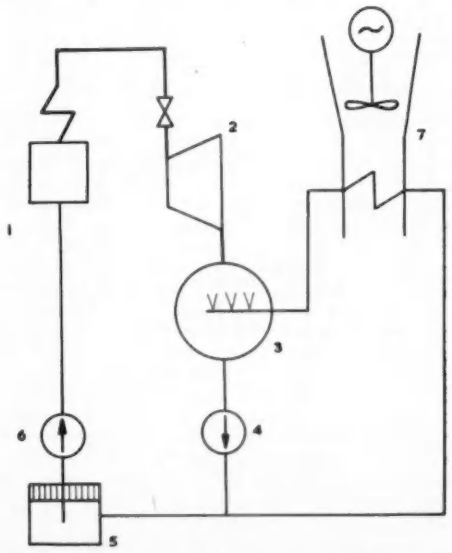

Fig. 3. **Diagrammatic representation of an air-cooled condenser plant.**

is of considerable interest in cases of water shortage.*

In other designs in which condensation is effected by air cooling, the dimensions of the heat exchanger must be increased considerably, in view of the appreciable volume of steam at pressures well below atmospheric which have to be condensed. An advantage of the method proposed by Heller and Forgö is primarily that direct condensation of the exhaust steam in the condenser is dispensed with. As shown in Fig. 3, the steam from the turbine (2) is fed into the spray condenser (3), in which it condenses as a result of the injection of finely atomized condensate into the steam. The condensate produced is fed by means of a pump (4) into the cooling tower (7), and is then returned to the spray condenser. Part of the circulating condensate, corresponding to the quantity of steam exhausted from the turbine, is pumped into the feedwater tank (5) and then fed to the boiler (1) by means of the feedwater pump (6). The use of the jet-condenser has the important advantage that its dimensions are considerably smaller than those of current surface-type condensers.

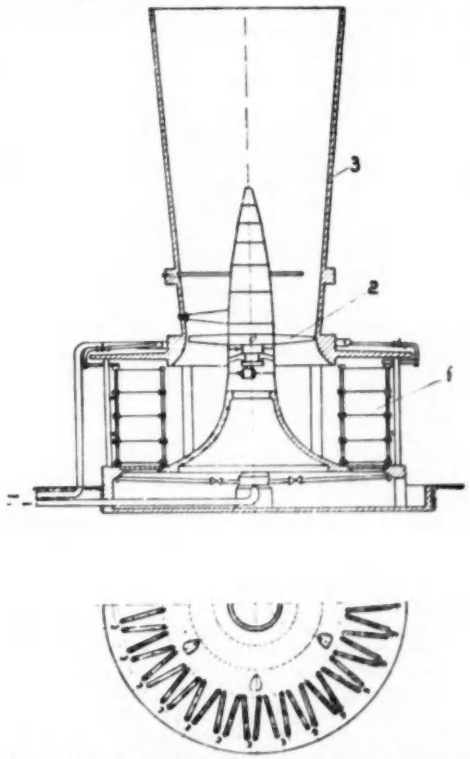

Fig. 4. Schematic layout of the cooling tower and its heat exchangers.

Fig. 4 shows diagrammatically the arrangement of the cooling tower and its heat exchangers, the tower (3) having a low-speed induced-draught fan (2) to ensure flow of the required quantity of cooling air in the tower. The heat exchangers (1) are arranged in star fashion at the base of the tower and their individual elements are made of corrugated finned aluminium tubes (Fig. 5).

* It has recently been announced that The English Electric Company Ltd. are developing a cooling system for power stations based on this principle. *Ed. E.D.*

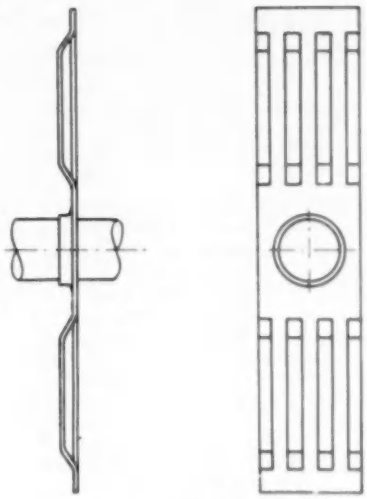

Fig. 5. Detail of heat-exchanger tube.

The advantage of these corrugated ribs is that their cooling surface is subdivided into a number of thin strips arranged in the direction of flow of the cooling air, eliminating the formation of an excessively strong boundary layer at their surface and hence considerably increasing the coefficient of heat transfer, which, depending on air speed, reaches 80 to 120 kcal/m²hr°C. As a result, removal of a considerable quantity of heat in the case of small temperature gradients is possible, without having to increase unduly the dimensions of the heat exchanger. The only possible disadvantage of the use of aluminium is the fact that the cooled condensate must not have an unduly high pH-value, since alkaline water is aggressive to aluminium.

Extended operation of an experimental tower, condensing steam from a small 5-MW condensing turbine, has proved that this method of air cooling is very promising. Despite the fact that the aluminium heat exchangers were sited in a dusty location, there was no serious dust contamination. Also, cleaning of the heat-exchanger elements was easily effected by spraying with water from a hose.

Operation of the tower during winter at considerable sub-zero temperatures has also proved completely reliable, although there is, of course, the risk that freezing-up of the heat exchangers may occur, unless adequate precautions are taken. An additional advantage of this method of condensation is that the temperature of the condensate can easily be controlled by adjusting the draught, e.g., by varying the speed of the fan.

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SWITZERLAND

Electronic Servo-, Programming, and Positioning Systems

By F. GLANTSCHIG. (From *The Brown Boveri Review*, Vol. 44, No. 11, November 1957, pp. 488–496, 8 illustrations.)

In our issue of January 1958, *we published an article on "The Application of Theory and Electronic Computers to Automatic Control." The following article discusses new devices for controlling machine tools, specially designed and developed for use with contour milling machines for shaping turbine blades, and for boring and milling machines.*

THE rapid progress towards automation has promoted the development of new devices for controlling machines, particularly machine tools, and, depending on the task to be performed, they must be able to pass on a set value or control order to the machine or its drive. These devices mostly operate on the analogue principle and are nearly always incorporated in a control circuit. In addition, devices are required which impart an appropriate order to the machine at a given instant or stage of the operation, and which must be able to store a number of orders, corresponding to the various functions, the orders being allocated to the functions in logical sequence.

Further tasks are performed by positioning and measuring devices which measure, control, or supervise the movement of the machine in two or three dimensions, in accordance with preset numerical values. Nowadays, the devices used for these purposes mostly employ the digital principle, in order to attain the high accuracy demanded, involving a relatively large number of control elements. Their adoption for medium and small machines has become economical only when reliable miniature components, such as transistors, cold-cathode valves, etc., became available, thus allowing the devices to be manufactured on the unit construction system with rationally produced parts and printed circuits. The construction of these devices is very like that of computers, elements of a similar nature being employed.

THE ELECTRONIC SERVO-CONTROLLER

For straightforward switching actions, relays are mostly used to operate electromagnets, solenoid-operated valves, or clutches, and for the excitation of d.c. machines. Many of the speeds and movements performed by machines, and machine tools in particular, must not only be controlled by On-Off sequences, but must also be variable in magnitude, and regulated and supervised. Since the speeds of modern machines must be infinitely variable in a wide range to meet the requirements of the process, the servo-mechanism employed must fulfil the conditions arising therefrom, as follows:—

(1) Transmission must take place without backlash, i.e., the transmission error must not exceed the tolerances of the particular task.
(2) The speed of adjustment should match the rate of change of the desired value, i.e., the speed of a servo-motor, for instance, must be infinitely variable.
(3) The operating time constants of the servo-mechanism must be as small as possible, and it must also be possible to adapt them to the time constants of the control circuit of the entire machine.
(4) To achieve good stability, the speed of adjustment must be adaptable to the magnitude of the difference to be made good.
(5) The control powers necessary must be as small as possible.

Naturally, all the above conditions cannot be entirely fulfilled, and a compromise must be reached which is acceptable to the particular conditions; this is usually possible only at the expense of other properties.

An electronic servo-controller developed by Brown Boveri fulfils the above conditions to a considerable degree and, in addition, enables individual characteristics to be specially stressed. Though primarily intended for use in conjunction with a servo-motor, it is equally suitable for feeding the excitation windings of d.c. machines.

In this controller, a simplified circuit diagram of which is shown in Fig. 1, the servo-motor is a shunt-wound d.c. motor, whose characteristic is ideally suited to the purpose. When its field is constantly excited, it exerts a constant torque from zero throughout the entire speed range. It is incorporated in a bridge circuit comprising the power valves V_1 and V_2 and d.c. sources G_1 and G_2. Opening one leg of the bridge causes the armature to rotate in the corresponding direction, thus affording controlled reversal of the servo-motor from one direction to the other through zero with hardly any play. In the state of rest the two valves are maintained at a basic current by the pre-control valve V_3. The two basic currents flow in opposite directions, so that outwardly, i.e., as far as the servo-motor is concerned, they cancel each other out. If the state of equilibrium of the bridge is upset by the control valve, the current in, say, V_1 increases proportionately, while that in V_2 decreases at the same rate. Thus, the full working current of the servo-motor is attained with only a slight change in the input level.

A stabilized d.c. voltage can be used but, when employed with variable-speed drives, this voltage is usually compared with the output of a tacho-generator. The difference is polarized by a voltage divider R_8–R_9, amplified in valve V_3 and used to control the power valves for the servo-motor. For straightforward follow-up control, two potentiometers form a bridge (e.g., P_1 and P_2 in Fig. 1).

The input voltage for the amplifier is fed in through the "symmetrizing" element in parallel with the rotor. This means that the armature voltage applied to R_1 or R_2 is connected in series with the anode voltage of the control valves. If the armature voltage, for instance, increases rapidly, it will cause the voltage drop across R_4 or R_3 to grow, thus producing a corresponding feedback and with it a damping effect. By means of the RC elements connected as differentiating and integrating elements in the grid circuits of the control valves, the response can be made to match the momentary conditions.

It is frequently necessary to introduce the effect of another quantity with drives and controls. The regulator can then be augmented by the elements within the dotted outline in the diagram. By suitable choice of the working point of valve V_4, the point at which this additional quantity takes effect can be varied. To adjust the magnitude of its effect the potentiometer P_3 is used. If, for instance, with a Ward-Leonard drive, a voltage proportional to the generator current is applied by shunting across the

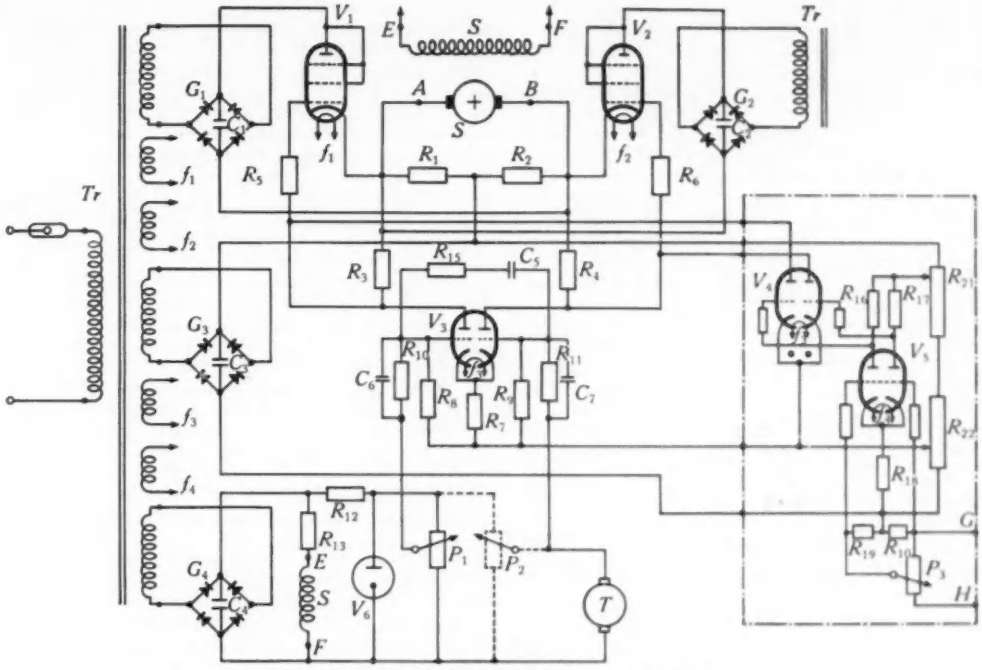


Fig. 1. **Simplified circuit diagram of the electronic servo-controller.**

A–B = Armature of servo-motor *S*.
E–F = Shunt field of servo-motor *S*.
G, H = Connections for additional control quantities.
Tr = Mains transformer.
G_1–G_4 = Rectifiers.
f_1–f_4 = Filament voltages.
V_1, V_2 = Power valves.
V_3–V_5 = Control valves.
V_6 = Voltage stabilizer.
R_1–R_{22} = Adjusting resistors.
C_5–C_7 = Capacitors.
P_1–P_3 = Setting potentiometers.
T = Tacho-generator.

terminals *G* and *H*, this additional element acts as a regulator for starting and braking.

Servo-Controller Containing Transistors and Relays

For complicated automatic machines, such as the contour-milling machine for shaping turbine blades to be described later, the servo-controllers are only a part of the complete control system, with which they are frequently combined to form an integral unit. Since systems of this kind, with their numerous electronic components, employ only transistors, germanium or silicon diodes, or cold-cathode valves, in order to ensure immediate readiness, long life, maximum reliability, and, above all, minimum space, it is almost inevitable that the same elements should be used in the servo-controllers.

Fig. 2 shows the circuit of such a device. The servo-motor, in this case also a d.c. shunt-wound motor, is switched in the appropriate direction by relays *A* and *B*. To prevent overswinging caused by the motor's moment of inertia, it is braked by short-circuiting the armature. The two relays are each energized by a monostable multi-vibrator with two transistors (Schmitt trigger). These produce a sharply rising current for attracting the relays, which operate without any flutter. In order that the sensitivity of the device may conform to the stipulated conditions, these triggers are controlled through pre-amplifiers. Coupling is galvanic throughout, so that the system responds to changes in a d.c. voltage level with a frequency of practically zero. Comparison of the desired and actual values is by means of a voltage bridge comprising the potentiometers P_1–P_5 which supplies the difference voltage required, polarized in the same manner as in the electronic servo-controller, and applied to the input of the pre-amplifiers. The sensitivity is approximately 50 mV at the pre-amplifier input, so that, with a comparison voltage of 24 V, a control accuracy of $\pm 0{\cdot}3\%$ is obtained. The Schmitt triggers and pre-amplifiers used are compact plug-in units employing printed circuits, enabling the unit-construction principle to be adopted to a large extent.

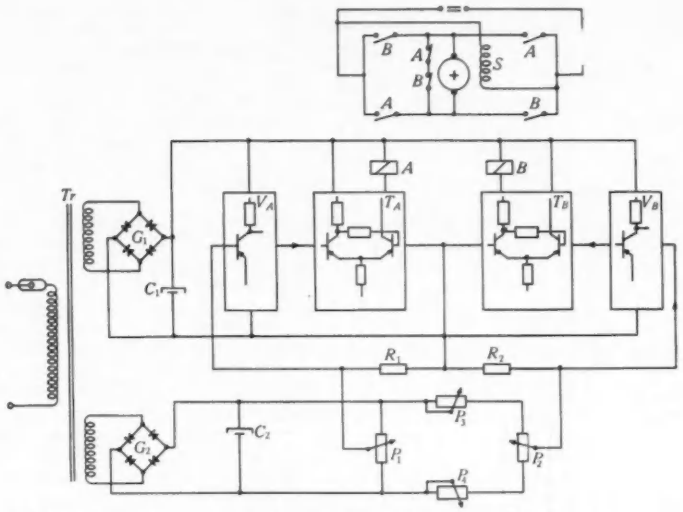
Electronic Programming Device for Automatic Contour-Milling Machines

The contour milling of blades for turbines and compressors, which has become necessary in recent years, has now reached a high state of perfection. In order to complete the shaping of a blade economically and accurately, a number of different milling processes are necessary, and these should be carried out without unclamping, if possible. This means that a machine of this kind must be able to perform several different movements, some of them exceedingly complicated. If control is to be automatic, a suitable system must be provided, with a means of memorizing and allocating the combinations in logical sequence.

Fig. 3 is a simplified block diagram of the electronic programming device developed by Brown Boveri for use in conjunction with a particular modern contour-milling machine for shaping turbine blades. The machine operates in three dimensions, i.e., the cutter can follow a curve in space. All movements are actuated hydraulically and, with the exception of the actual copying motion, which follows a guide on the specimen, are con-

Fig. 2. **Circuit diagram of a servo-control using transistors.**

S = Servo-motor.
A, B = Relays.
G_1, G_2 = Rectifiers.
Tr = Mains transformer.
C_1, C_2 = Capacitors.
R_1, R_2 = Resistors.
P_1 = Feedback potentiometer.
P_2 = Desired-value potentiometer.
P_3, P_4 = Potentiometers for limiting at upper and lower ends.
T_A, T_B = Schmitt triggers.
V_A, V_B = Transistor pre-amplifiers.



trolled electrically. The machine can produce continuous main feed, pick feed, and a copying motion all at the same time. The allocation of these movements to the various directions differs from one milling process to another and can be pre-set according to requirements. Electromagnetic valves are provided for selecting and reversing the hydraulic movements. The servo-mechanism described, containing transistors, is used to control the main- and pick-feed motions. Squirrel-cage motors drive the cutting spindles, the pump of the hydraulic system, and various auxiliary devices.

For position indication there is one pair of limit switches for the longitudinal and vertical directions respectively (E_3 and E_4 in Fig. 3), while for the lateral direction two pairs are required, E_1 and E_2. A further pair of limit switches E_5 cuts in the choke before the slide strikes the end-stop. The duties of the limit switches vary according to the milling programme, the allocation being performed by the programming device.

For each function of the machine there is a selector with 2 × 4 positions. To set up a particular milling programme, a template has to be used for marking the positions of the various selectors. Six potentiometers are provided for preselection of the various main- and pick-feed speeds for a particular milling programme. These

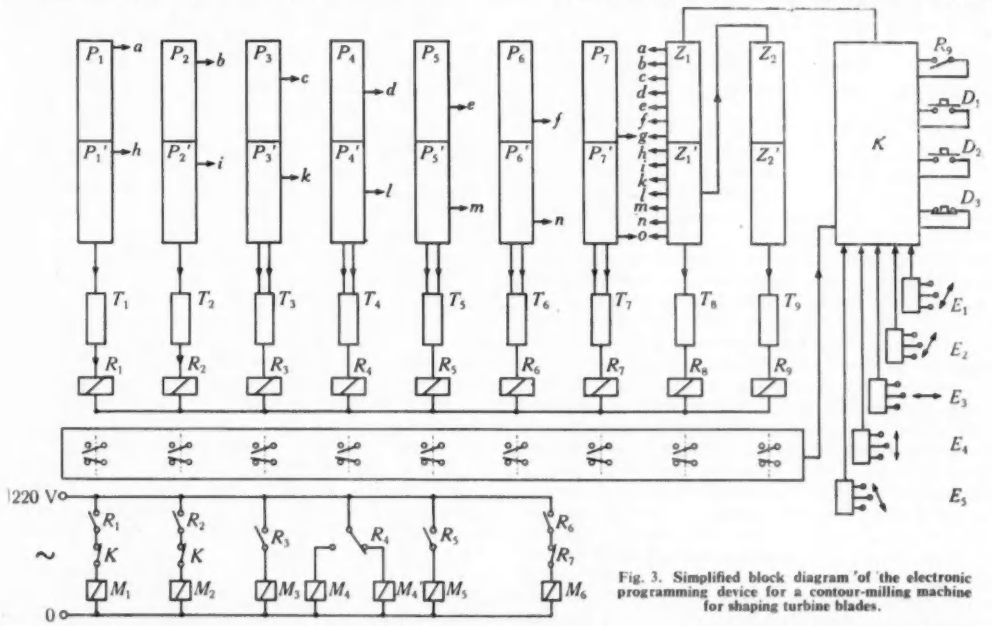

P_1 P_2 P_3 P_4 P_5 P_6 P_7
P_1' P_2' P_3' P_4' P_5' P_6' P_7'
a b c d e f g h i k l m n o
Z_1 Z_1' Z_2 Z_2'
K
R_9
D_1 D_2 D_3
T_1 T_2 T_3 T_4 T_5 T_6 T_7 T_8 T_9
R_1 R_2 R_3 R_4 R_5 R_6 R_7 R_8 R_9
E_1 E_2 E_3 E_4 E_5
220 V
~
0
K
M_1 M_2 M_3 M_4 M_5 M_6

Fig. 3. **Simplified block diagram of the electronic programming device for a contour-milling machine for shaping turbine blades.**

P_1–P_7 = Function selectors.
Z_1, Z_2 = Cold-cathode counting rings.
T_1–T_9 = Multi-vibrators as impedance transformers and amplifiers.
R_1–R_7 = Evaluating relays for the various functions of the machine.
R_8 = Relay for resetting the function selectors after a run.
R_9 = Zeroing relay.
K = Relay combination for filtering the impulses suitable for triggering from the train emitted by the limit switches.
E_1–E_5 = Limit switches on the machine.
D_1 = Push-button "Programme start".
D_2 = Push-button "Interrupt".
D_3 = Push-button "Restart".
M_1–M_6 = Solenoids of hydraulic control valves.

speeds are then held constant along the curve to be cut by a system of follow-up control acting through the servo-controller. The corresponding minimum and maximum values can also be preset on the potentiometers. The circuit arrangement is such that the individual movements can also be manually controlled. To select the method of control, a switch for automatic or manual operation is provided. The individual functions can be set by means of separate switches. Manual control is primarily intended for setting up the machine.

The basic element of the programming system is the cold-cathode counting ring, of which two decades in series form a scale of twenty, two such scales being used. By carrying on one counting impulse to the second ring when the first finishes a count, the cycle of nineteen steps can be repeated nineteen times. The cold-cathode ring is triggered by the impulses received by the machine from the limit switches through a logical filter ; hence, only those impulses which denote the course of the programme according to the logical allocation are effective.

The impulse filter consists of relays and contains all interlocks necessary for the machine. The gates of the filter are set by the contacts of the functional relays R_1–R_9. Simultaneously, these relays actuate the solenoids of the control valves through heavy-current contacts.

Corresponding to each scale of twenty there are also two groups of four decade selectors for each function of the machine. Each of these selectors has four independent marking systems (on printed circuits), each with a cold-cathode valve to supply the output impulse. This valve is fired, according to the programme, by the transfer impulse. As a result of the high-impedance impulse so obtained, the functional relays still cannot pick up ; hence, multi-vibrators are connected after them as impedance transformers, which, depending on their function, may be mono- or bi-stable. In the latter case triggering is effected over two separate channels.

The number of counting cycles is fixed according to the position of the zero marking. This returns the cold-cathode counting rings to zero, but a new programme cannot begin until the order " programme start " is given by means of a push-button. If, for a certain count, all nineteen steps are not required, it is possible either to reset directly to zero or, if the programme is to continue cyclically, the remaining steps are filled by a train of impulses produced by the impulse filter, the start and finish of the train being marked by selectors incorporated in the counting rings.

Once a programme has started, it can be interrupted at any point and restarted at the same point, if so desired, by operation of appropriate push-buttons. If the programme is interrupted, the movements just switched are stopped, the cutter is raised from the workpiece, and the tool and cooling pump stopped. The programme is restarted in the reverse sequence.

The subdivision of the block diagram corresponds to the layout of the device. Use of printed circuits is made in the various plug-in sub-units, and identical sub-units are interchangeable. The central control panel on the

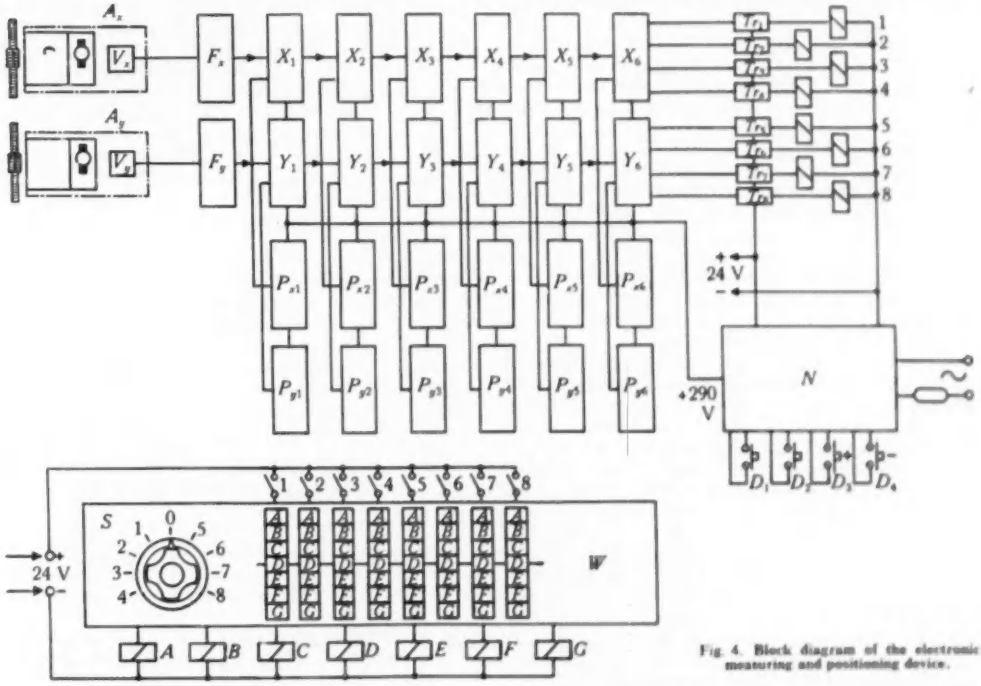


Fig. 4. Block diagram of the electronic measuring and positioning device.

Ax, Ay = Digitizers for the two co-ordinates.
Vx, Vy = Transistor amplifiers in the digitizers.
Fx, Fy = Impulse formers for triggering the counting rings.
X_1–X_6, Y_1–Y_6 = Cold-cathode counting rings of the X and Y co-ordinates.
Px_1–Px_6, Py_1–Py_6 = Four-way position selectors.
Tr_1–Tr_8 = Output triggers.
1–8 = Position relays.
S = Programme selector switch.
W = Function selector.
N = Power pack and auxiliary relay.
D_1–D_4 = Push-buttons for " Start ", " Zero ", and " Zero correction ".

front of the unit, in addition to the elements directly concerned with programming, also contains the push-buttons for controlling the various motors, several selector switches and push-buttons for controlling the machine manually, two potentiometers for independent regulation of the main- and pick-feed drives, and an emergency button.

The operator in charge of a machine equipped with this sytem of controls, having once set up the machine, has only to clamp and unclamp the workpiece and press the start-button each time. Since the machining times are usually considerably longer than the clamping times, it is quite possible for an unskilled worker to control several machines at once.

Electronic Measuring and Positioning Device with Programming of Machine Functions

A further inportant advance in the automatic control of a machine is achieved when, in addition to controlling the entire movement of the machine automatically, as regards the starting points, direction, and speed, its position and the speed of these movements are known at every point or every instant. Then, the desired general functional allocation for such controls becomes possible. This aim can be attained only by means of continuous measurement. It is made possible—particularly when very high accuracy is specified—by dividing the distance to be measured into incremental steps, the length of which depends on the degree of accuracy stipulated. The number of increments per unit length is known as the resolving power, and these sections are counted numerically by a suitable device. Assuming that a resolving power of 100 per millimetre is specified, the numerical value of the desired position is the same as its dimension in hundredths of a millimetre. With a single position value, only a linear movement from a datum point can be defined. For combinations of straight lines, for mathematically defined curves, and, above all, for empirical curves, a very large number of such values is necessary. The programming of these values is possible only for complicated shapes with the aid of an electronic computer with a memory. It is obvious that such installations involve a great deal of equipment, are very complicated, and are correspondingly expensive.

An electronic measuring and positioning device, developed by Brown Boveri for use with vertical and horizontal lathes, milling machines, and jig-borers, incorporates the above principles and uses a unit system of construction, with sub-units built up on printed circuits. The device is designed for two co-ordinates and includes two visual indicators, on which the distance can be read off directly in hundredths of a millimetre. The counting elements are cold-cathode rings wth a maximum counting rate of 2000 impulses per second. Thus, with a resolving power of 100 impulses to the millimetre, the maximum positioning speed is 1·2 m/min. The device can count up to a total of 999,999 impulses, which, with the resolving power chosen, represents a length of 10 m.

With this particular device it is necessary for only four points per co-ordinate to be automatically controlled. For this purpose, four-way selector switches are mounted beneath the visual indicator corresponding to the individual decades of each co-ordinate. The device also contains a programme selector switch and a function selector ; the former enables one of the four or eight preset positions to be selected in any order, while the latter relates a particular function of the machine, such as slow, stop, reverse, etc., to a definite position.

With a further selector the counting rings of the two co-ordinates can be switched in parallel onto one of the digitizers, so that eight alternative positions are provided. To fix measured distances, a memory switch is provided for each co-ordinate, the result of the measurement being retained, regardless of subsequent movements when the switch is actuated. The block circuit diagram (Fig. 4) shows the layout of the device and its division into the various sub-units, which, with the exception of the power pack and the relay control system, are plugged in and interchangeable.

The digitizer specially developed for this purpose operates according to a photo-electric process in the range between 0 and 3000 cps. The position is measured by means of a precision toothed bar, the overall error of which is less than 8 μ. The same degree of tolerance can be achieved for digitizing by suitable design of the precision gear and photo-electric system. For every revolution of the rigidly mounted driving pinion, 15,000 impulses are emitted, and these are brought to the amplitude and waveform suitable for reliable transference by a transistor pre-amplifier in the digitizer.

Special circuits allow positive or negative adjustment to compensate for tool wear, to correct the cut, or to introduce a differential movement. From the digitizer the impulses proceed to a further amplifying and forming stage, in which the impulses needed to control the cold-cathode rings are produced. Conforming to the values to be positioned, the desired numbers of impulses can be marked in the position selectors belonging to the decade counting rings. When this number is reached, the last impulse appears as an output impulse and triggers the positioning relay, which, through the function selector, switches those relays which, with their heavy-current contacts, interfere in the control of the machine. Every position order, on reaching its value and after an adjustable output impulse, is either automatically erased or held in preparation for a new measurement. Zeroing and starting can also be actuated externally.

The measuring point is quite independent of the reading scale, since the transmission is performed electrically and no complicated optical system is required. The measured distance appears as a numerical value, thus avoiding errors of observation, such as when a vernier is used. Since the device can be set to zero at any point, every measurement can be made from any point, unlike optical measurement, where it is often necessary to start from a point having an awkward numerical measurement. With the electronic method, automatic positioning is also possible.

Titanium-Plating Processes and Properties of Coatings

(*Concluded from page 57*)

steel, nickel, copper, and other metals. In general, the best plates are obtained with melts containing reduced titanium mixtures such as titanium dichloride/titanium trichloride.

Many of the processing variables applying to electro-decomposition plating also apply to soluble-anode plating. Current density is quite important in soluble-anode plating and must be controlled for both the anode and cathode. Current density must be substantially less at the anode than at the cathode, and for this reason the surface area of the anode must be appreciably greater than the area of the cathode (i.e., the part to be plated).

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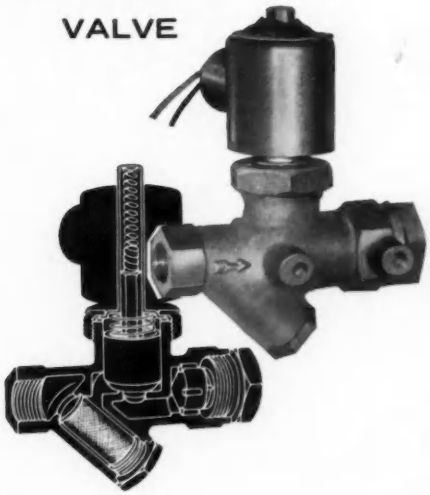

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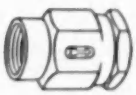

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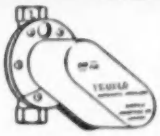

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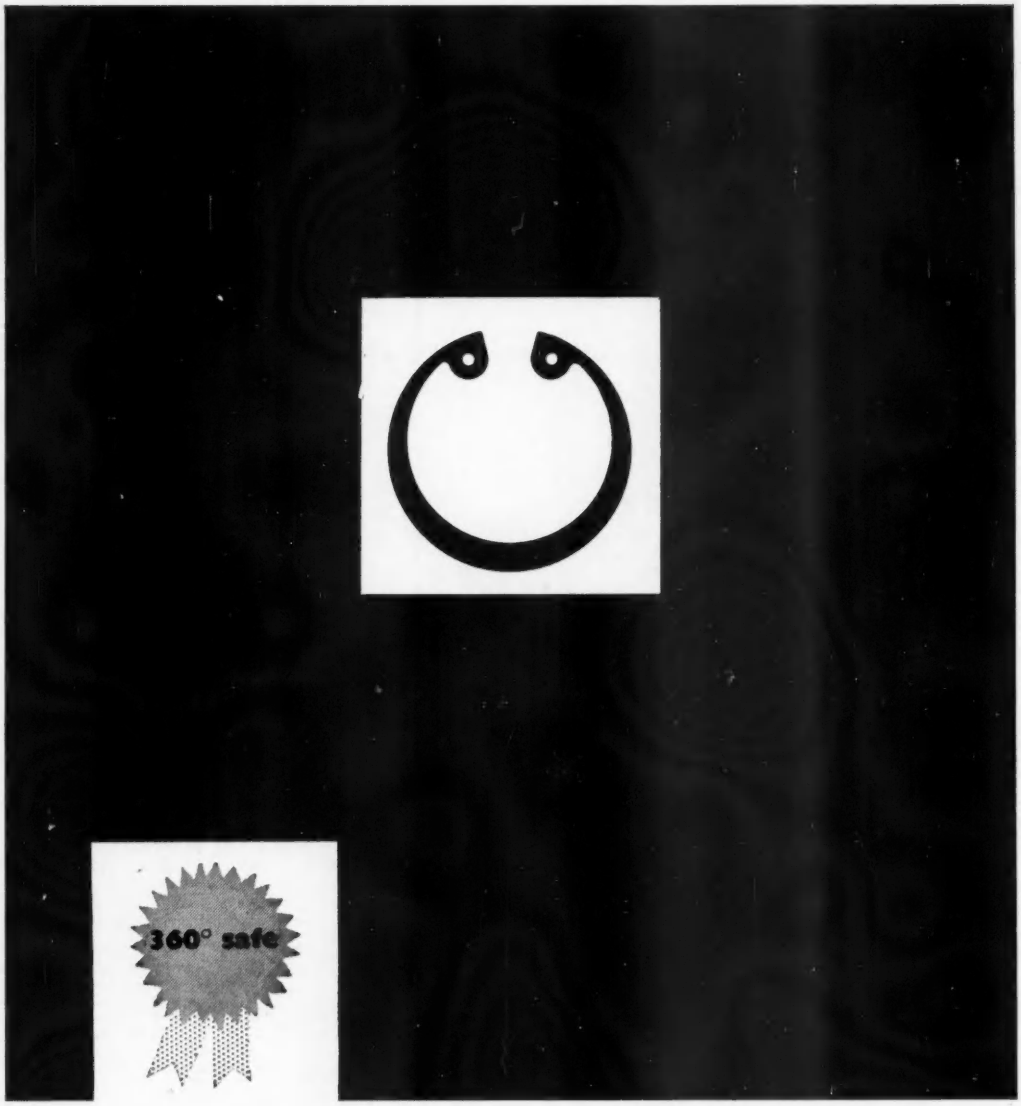

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British Industrial Developments

Progress in Thermonuclear Research

The results of recent research at the Atomic Energy Research Establishment, Harwell, have led to the conclusion that control of thermonuclear reactions for electricity generation may well eventuate, although its practical application still appears to be a long way off. In connection with this work, a large installation, designated ZETA (i.e., zero-energy thermonuclear assembly) has been constructed, its purpose being to study the reaction in which deuterons collide with each other to fuse and form heavier nuclei, releasing energy and some neutrons in the process. For fusion to be possible, the deuterons must have enough energy to overcome the initial electrical forces of repulsion between them, necessitating heating the deuterium gas to extremely high temperatures. Furthermore, the hot gas must be kept away from the walls of the container ; otherwise, it falls in temperature.

The principle adopted in ZETA, a general view of which is shown in Fig. 1, is to pass a large electric current through the deuterium gas. This current sets up an electrical discharge in the gas, heating it and also producing an intense magnetic field around the column of hot gas. This magnetic field causes the discharge to become constricted and hence heated still more and, since it also causes the discharge to " wriggle " about, this field by itself is not enough to keep the discharge away from the walls. The wriggling has been suppressed by applying an additional steady magnetic field parallel to the axis of the tube. An artist's impression of the thermonuclear flame is shown in Fig. 2.

In ZETA the discharge chamber is a ring-shaped tube or torus of 1 metre bore and 3 metres mean diameter, containing deuterium gas at low pressure. The tube is linked (i.e., encircled over part of its length) by the iron core of a large pulse transformer. A current pulse of electricity is passed into the primary winding of the transformer from a bank of capacitors capable of storing 500,000 joules of energy. This pulse in turn induces a very large unidirectional pulse of current in the gas, which forms a short-circuited secondary for the transformer. Peak currents up to 200,000 A have been passed through the ionized gas for periods up to 5 millisec. The current pulse is repeated every 10 sec, and emission of neutrons throughout the pulse has been observed regularly in routine operation of ZETA with deuterium, up to 3×10^6 neutrons being emitted per pulse.

The temperature of gas discharges may be determined from measurements on the light emitted by the gas atoms, but measurements of this kind in these experiments present problems, because, at the temperature of the discharge, the hot deuterium atoms are completely stripped of their electrons and therefore do not emit a line spectrum. One method of solving this problem is to mix with the deuterium a small quantity of some heavier gas, such as oxygen or nitrogen, the atoms of which are not stripped of all their electrons under these conditions, and to study the spectral lines emitted by this impurity ; the random motion of the high-energy impurity atoms, which make many collisions with the deuterium atoms and so reach the same energy, causes the spectral lines to broaden, owing to the Doppler effect, and the amount of broadening is a measure of the ion energy. Many measurements by this method have indicated temperatures in the region of 2×10^6 to 5×10^6 °C. Whilst temperatures in this range are required to explain the observed rate of neutron production on the basis of a thermonuclear process, electric fields in the gas, arising from instabilities, can also accelerate deuterium ions and lead to nuclear reactions. Such a process was described by Kurchatov in his lecture at Harwell in 1956, so that it is not altogether certain that the observed neutrons come from a thermonuclear reaction. Admittedly, there are good reasons to think that they are derived in this way, but it is also true that they could arise from other reactions, such as collision of deuterons with the walls of the vessel, or from bombardment of stationary ions by deuterons accelerated by internal electric fields produced in some forms of unstable discharge. Experiments are continuing to study the details of the neutron-producing processes. In the ZETA apparatus the number of neutrons produced by each pulse of energy as the current was doubled was roughly that which might be

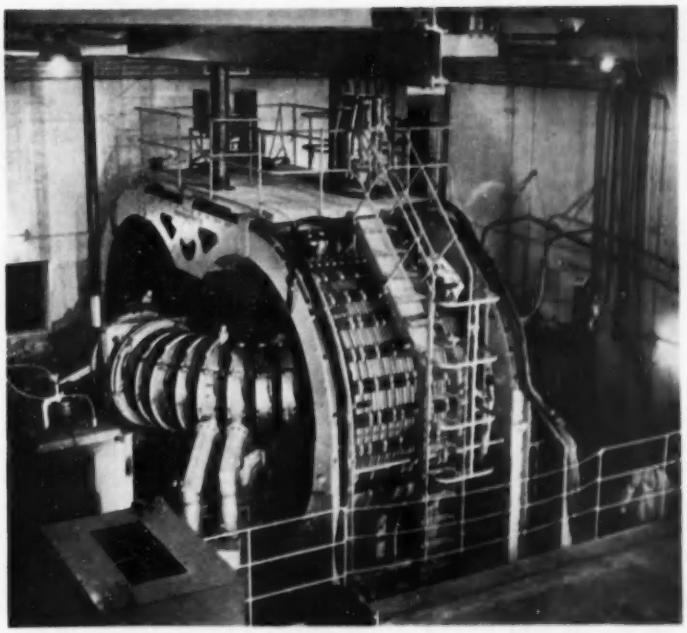

Fig. 1.

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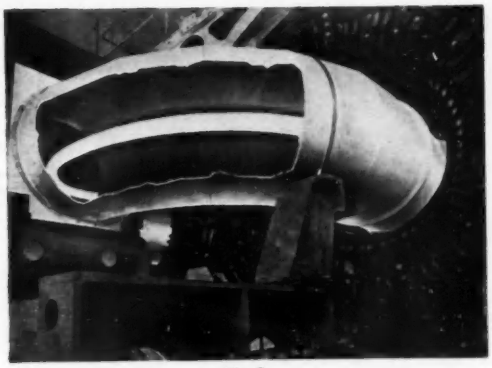

Fig. 2.

expected from a thermonuclear reaction at the measured temperatures. These temperatures have been definitely established.

Following the success obtained with ZETA, it is interesting to note that a similar discharge has been produced and high temperatures obtained more economically at the Research Laboratory of Associated Electrical Industries Limited, using a smaller apparatus, designated " Sceptre III ". This apparatus (Fig. 3) is an aluminium torus, made of tubing about 30 cm in diameter, the mean torus diameter being approximately 114 cm, and is threaded by an iron core weighing 4 tons. Numerous experiments have been carried out with this equipment, discharging into it energies up to 40,000 joules. Currents up to 200,000 A have been generated and temperatures up to nearly 4×10^6 °C have been measured. At temperatures between $2{\cdot}3 \times 10^6$ and $3{\cdot}8 \times 10^6$ °C, neutrons are emitted copiously over a period of several hundred microseconds, during which time the discharge channel appears to be stable. Many experiments have been conducted to establish the conditions under which the neutrons are emitted, and the manner in which the

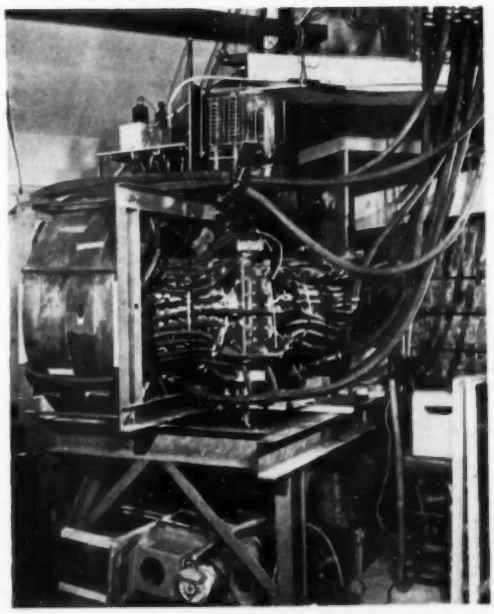

Fig. 3.

number emitted varies with gas pressure and temperature and with different values of the stabilizing magnetic field, and it is hoped to improve the efficiency of the use of electrical energy to achieve a plasma of even higher temperature.

In order to obtain a net gain in energy from the reaction it would be necessary to heat deuterium gas to temperatures in the region of 100×10^6 °C, and to maintain it at this temperature long enough for the nuclear energy released to exceed the energy needed to heat the fuel and lost by radiation. Lower temperatures would suffice for a deuterium-tritium mixture. The high temperatures achieved in ZETA and the relatively long duration for which the hot gas has been isolated from the tube walls are the most important experimental results obtained so far. Whilst a much longer time (perhaps several seconds) is required for a useful power output, there appears to be no fundamental reason why these longer times, together with much high temperatures, cannot be achieved. There are, however, many major problems still to be solved before its practical application can be seriously considered, and the work must be expected to remain in the research stage for many years. Certainly, however, if it eventually proves possible to construct a power station operating on the fusion of deuterium, there can be no doubt that a virtually inexhaustible source of fuel will be available from ordinary sea-water.

Pneumatic Suspension Systems for Vehicles

Experiments with pneumatic suspension systems are being carried out on their bulk-liquid transporters by Thompson Brothers (Bilston) Ltd., of Bilston, Staffs., and have so far been so successful that quantity production is contemplated in the near future.

Eliminating the inherent disadvantages of laminated leaf springs, i.e., constant rate, varying periodicity, and unpredictable inter-leaf friction, the pneumatic suspension system operates on the principle of compressing a volume of air trapped in a concertina-shaped, nylon-reinforced rubber bellows. In a typical example, the body of the bulk-liquid transport tank bears on the axle through two or more of these bellows, which are filled with compressed air from a reservoir whose pressure is maintained by the air-brake system of the vehicle. In the unlikely event of failure of the suspension, the brakes are safeguarded by a non-return valve. The flow of air from the reservoir to the bellows is controlled by two levelling valves, which maintain the static height of the vehicle at a constant figure, irrespective of the load being carried. Thus, as distinct from conventionally sprung vehicles, the full travel of the springs is always available to absorb road shocks.

Air-suspension systems of this type adjust themselves automatically to suit the load being carried and are thus just as soft when unladen as when laden. Other advantages are that, as there is virtually no internal friction in an air spring, the system will function as designed, independently of the factors governing leaf-spring friction, while the elimination of all conventional greasing points reduces maintenance costs.

Midget Electric Screwdrivers

Designed for continuous operation, the Bosch high-frequency miniature electric screwdriver, model HR42/14, distributed in the U.K. by Trend Industrial Equipment Ltd., of Stanmore, Middlesex, can be adjusted to tighten nuts and screws to a predetermined torque which remains constant, thereby making it especially suitable for assembly work. This screwdriver weighs only 15 oz and can be suspended from a spring-balancer, as shown in the illustration, thus providing a convenient means of bringing it down on the screw head and then releasing it again.

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* *Figure supplied by Gt. Raymond Paper Co. of Lac Brûlé, Canada.*

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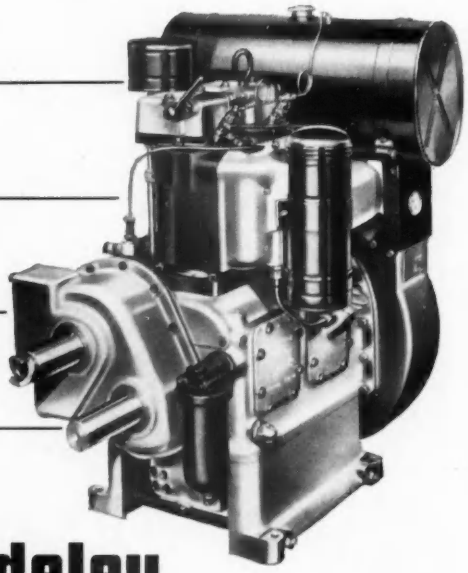

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AIR COOLED Diesels

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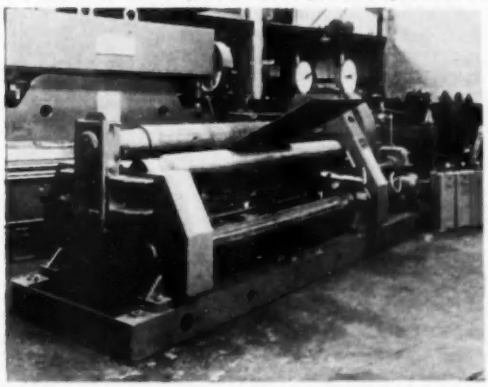
Various models are available for accommodating different sizes of nuts, bolts, and self-tapping screws, and all are designed to operate from a 3-phase a.c. supply of 42 V at 300 cps, requiring the use of a frequency changer. A suitable 4-kVA frequency changer is available and is capable of operating up to fifteen screwdrivers simultaneously.

4-Roll Initial-Pinch-Type Plate-Bending Rolls

With a capacity for bending mild-steel plate up to 8 ft in width and $\frac{3}{4}$ in. in thickness, the 4-roll initial-pinch-type plate-bending rolls shown in the illustration can bend to a circle with the absolute minimum amount of flat on the long edges with only one rolling pass. A unique feature of this machine, which has been built by The Bronx Engineering Co. Ltd., of Lye, near Stourbridge, is the fitting of a skid-plate to permit the rolling of cones in one pass, in the same way as cylinders, thereby eliminating the normal tedious method of working to datum lines required for 3-roll pyramid-type plate-bending rolls.

The centre bottom roll is adjusted vertically for gripping the plate and is operated from a conveniently located handwheel. The two side bending rolls are individually adjusted by means of separate 10-hp reversing motors, directly coupled to worm gearing in the housings and controlled by push-buttons. The top roll is fixed, but the bottom pinch roll is adjustable up and down for plate thickness and, like the two outside bending rolls, can be tilted for conical work. A multi-jaw clutch is arranged on each driving shaft, so that one end of the roll is operated for conical setting. The positions of the side bending rolls are shown by pointers on a graduated scale mounted alongside the roll chocks, and by dials mounted on top of the machine at the operator's position. The top roll is provided with a long counterbalancing extension for retaining the roll when the end-bearing swings down. A support is provided at the extreme end of the machine, engaging the ball end of the roll and operated by means of a handwheel. Limit-switches are fitted to the side bending rolls to prevent damage to the machine, should they be accidentally overrun either up or down, while a magnetic brake is fitted to the 15-hp main drive motor to eliminate overrunning of the rolls.



The brake-jaw or skid-plate is fitted on the right-hand housing for the rolling of cones or tapered shells, the action being that the small side of the plate which will form the small diameter of the cone will skid on the face of the plate and make up for the difference in the two cone diameters.

Continuing Graphite-Electrode Salt Baths

Providing a practical and economical method of heat treatment, the Efco-Upton continuing graphite-electrode bath, recently introduced into the U.K. by the Electric Resistance Furnace Co. Ltd., and based on proving tests by their associates, Upton Electric Furnaces Ltd., of Detroit, Michigan, have the main advantage of being able to renew electrodes without having to take down any part of the furnace brickwork.

The electrodes consist of cylindrical graphite rods which are fed horizontally through opposing walls at the bottom of the refractory lining, as they are consumed, whilst the furnace is still in operation. Moreover, a fresh electrode can be attached to the screw-feed device, again without interrupting operation of the plant ; hence, the full life of the furnace lining can be utilized—an advantage never before possible with submerged electrodes. Since the electrodes are submerged, with the only end faces exposed to the salt, electrode wear is reduced to a minimum and their life increased.

With the special dense high-temperature bricks used, a lining life of 12 to 18 months is achieved at high-speed steel-hardening temperatures, and 3 years on neutral hardening up to 1000° C, while a life of 5 to 10 years is not uncommon on aluminium brazing. In addition, the special lining bricks used result in a negligible amount of salt absorption into the lining, whereas, with conventional refractory linings, practically the same volume of salt is absorbed by the brickwork as is contained in the actual pot. This point is of particular importance in high-speed and brazing baths, where the salt (or flux) is a comparatively expensive item.

Another advantage is that, with the electrodes located

Putting two and two together and making five ! At least, that's how it appears when you consider the saving in time and cost by changing over to tapping screws. Without doubt, the tapping screw does display a number of very definite advantages over the conventional machine screw. It obviates the use of nuts. With its self-locating point, it forms its own thread and eliminates a separate and expensive tapping operation. It makes for easier assembly, is stronger, cheaper and faster. And when used in conjunction with the Phillips recessed head, designed for power driving without damage to either work or worker, it is obviously safer. Putting two and two together, the tapping screw simply ensures a better job. Why not change over to tapping screws and prove it for yourself?

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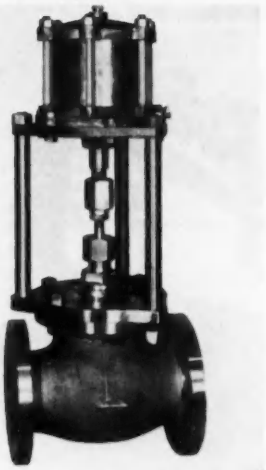
in the very bottom of the bath, the entire exposed surface of the salt and operating depth are available as work space. Here again, the absence of any metal which could result in the presence of metallic oxides in the bath facilitates maintenance of the neutrality of the salt in hardening operations and obviates premature breakdown of the flux in aluminium brazing.

Cylinder-Operated Valves

A new range of cylinder-operated valves, suitable for saturated steam up to 300 psi, superheated steam up to 250 psi and 500°F, and oil and water up to 500 psi at 150°F, is announced by Hunt & Mitton Ltd., of Birmingham. These valves are available in sizes from 1 to 4 in., with flanged connections, and are supplied in two types, i.e., air to open, or air to close.



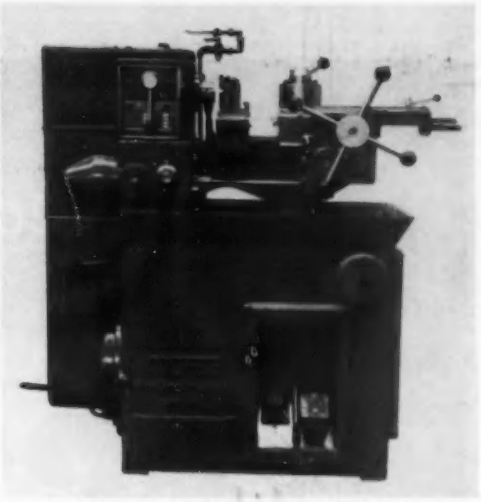
The body of the valve is of the globe type, manufactured from a bronze casting, and is fitted with a bolted cover, renewable nickel-alloy valve discs and seats, and an amply dimensioned stainless-steel spindle. The cylinder, which is secured to the cover by heavy mild-steel pillars, is suitable for operating air at 60 to 110 psi, and may be of the double-acting type or single-acting type with spring return.

Small-Capacity Capstan Lathe

Introduced as a high-quality small-capacity unit in the low price range, the " Flying Half Inch " capstan lathe announced by Murad Developments Ltd., of Aylesbury, Bucks., is nevertheless designed to offer optimum conditions for machining a wide range of ferrous and non-ferrous materials, and is equipped with six spindle speeds, forward and reverse, from 355 to 4000 rpm.

All slides are equipped with fully adjustable stops, and the slideways are hand-scraped to 0·0005 in. alignment. The short spindle is driven by a V-belt and accommodates dead-length collets capable of gripping round bar up to ½-in. in diameter. A fully automatic spindle brake is fitted, which engages whenever the forward/reverse lever is in the central neutral position. The controls are finger-light and respond instantaneously to manipulation, while controlling movements have been reduced to a minimum For example, the pneumatic bar feed is interlocked with the collet, so that, by operation of only one control, the collet is opened, the bar fed to length, and the collet reclosed.

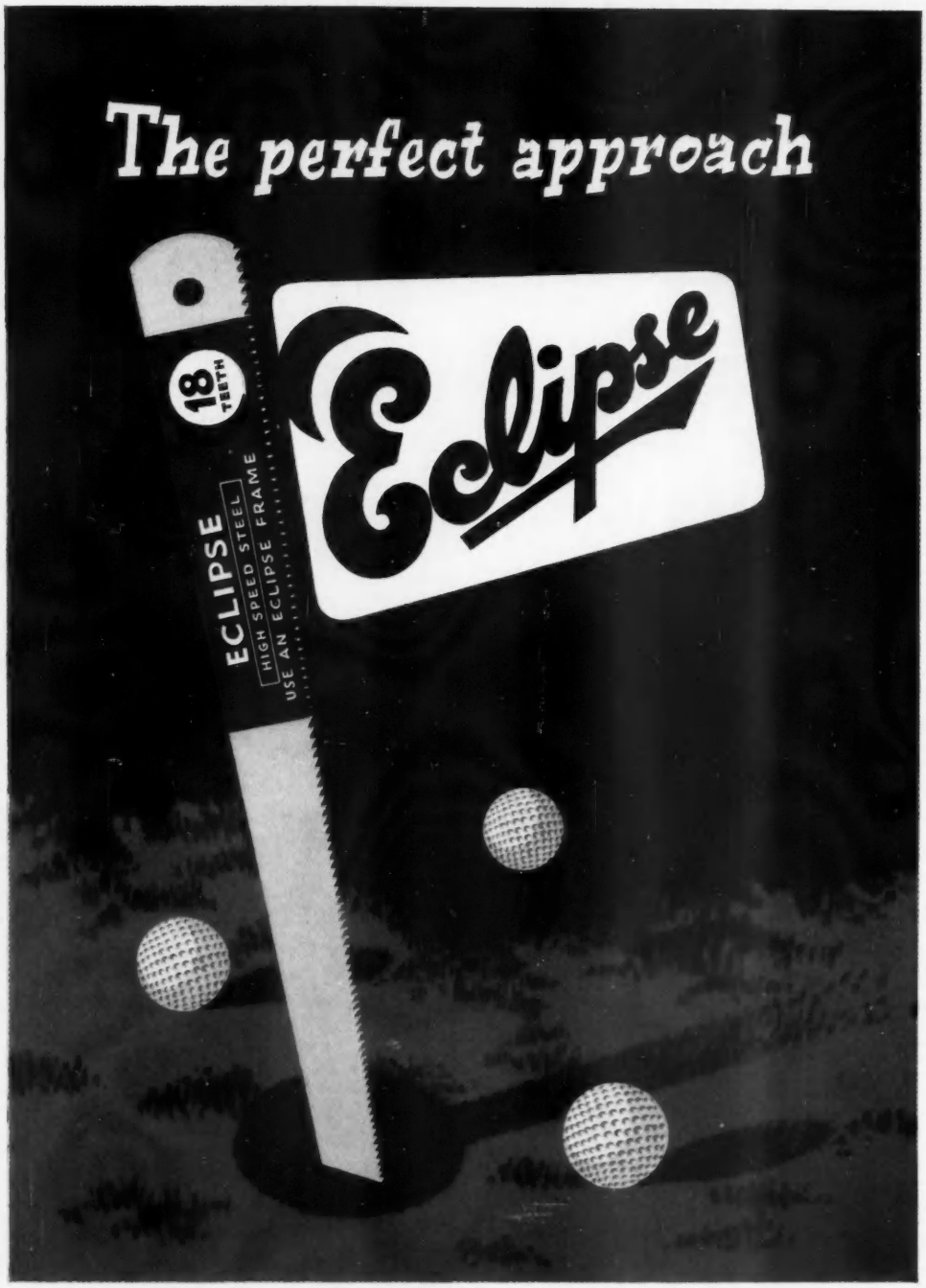
Three versions of the machine are available. Of these, model " OA " has a lever-operated collet and hand feeds to the turret slide, while model " OB " has a lever-



operated collet and three rates of power feed to the turret slide, and model " OC " has pneumatic pedal operation of the collet and three rates of power feed to the slide. All gearboxes on models " OB " and " OC " are automatically lubricated by a built-in oil pump. In addition, the collet mechanism of model " OC " is actuated solely by pneumatic power, and is held firmly closed mechanically in the event of failure of the air supply.

Induction-Heating Methods for Blowpipe Manufacture

A new induction-heating coil of special design is now being used for the manufacture of " Saffire " hand welding and cutting blowpipes by British Oxygen Gases Limited (Equipment Division). The brazing assembly consists of three stainless-steel tubes connected to an angle nozzle head, together with hard brazing rings. Using the orthodox method of brazing, the assembly was fixed in position on a " rise-and-fall " table, which was



'Eclipse' hacksaw blades and other tools are made by James Neill & Co. (Sheffield) Ltd. and are obtainable from all tool distributors

UH24

raised to allow the tubes to pass through a closed coil until the assembly reached the brazing position. After the components had been subjected to a rapid air quench, the table was lowered, so that the assembly could be removed.

During the period when the table was in operation, the induction heating machine lay idle, and it was decided that production could be increased if a new type of coil was designed which would eliminate the need for the table to be used. The new coil is constructed in three parts. Two water-cooled forks are made to fit the contour of the component, with a slight taper at the front of each member, these being attached to a fixture of insulating material and mounted on a fixed pedestal. A wedge-piece, with a taper corresponding to the taper on the forks, is then attached to the work-holding fixtures and made to slide horizontally in runners on the fixture holding the coil, the wedge-piece completing the circuit. A micro-switch is attached to a runner on the coil-holding fixture, to ensure that the current cannot be switched on until the work is in position, thus preventing arcing. The three tubes, angle-head, and brazing rings are slid into the split coil, and the induction-heating machine completes its brazing cycle immediately.

This new coil and fixture have enabled the advantages of the induction method of brazing to be fully utilized. While the brazing operation is being carried out, an additional work-holding fixture can be loaded, thus ensuring maximum machine utilization and increased productivity.

Resistance Welder for Laboratories

Primarily designed for research work into either spot, seam, roll-spot, or projection welding, the model UAM. 150 resistance welder announced by Sciaky Electric Welding Machines Limited, of Slough, Bucks., can also be used for production runs, if required.

To make the machine suitable for practically every kind of metal, the pressure head is pneumatically controlled, and provision is made for one, two, or three pressure cycles. A frictionless roller-bearing diaphragm head is fitted. The fully electronic Sciaky control panel allows for extremely accurate timing control from ½ cycle upwards, phase-shift stepless heat control, slope control, and preheat and/or post heat. Three fully synchronous basic Sciaky dekatron timers, plus motor control, give an almost infinite combination of machine settings. The machine-control circuit and time-control equipment are housed in a separate cabinet to eliminate any inaccuracies due to vibration or interaction from welding-transformer fringing fluxes. For ease of maintenance, all the doors and covers of the control cubicle may be quickly removed. The timing circuits, etc. are mounted on a reversible draw-out chassis.

Two lower arms are supported on pillars, one on each side of the machine. The seam or roll-spot arm, when clamped into position, engages with a shaft from the infinitely variable speed motor/brake unit. For spot welding, the lower arm, equipped with a tee-slot platen, is used in conjunction with bolted-on electrode holders. The arm not in use may be swung through approximately 180 deg., to lie along the main frame of the machine, well clear of the operator. As an aid to the seam-welding of coated materials, an extra tool is available for knurling the electrode faces.

Viscous Impingement Filters and Air-Cleaning Panels

It is announced by Intermit Limited, one of the Birfield Group of Companies, that they have negotiated licences to manufacture in the U.K. two American designs of air-filtration and gas-cleaning plant and related equipment and are now in full-scale production of " Far-Air " viscous impingement filters and " Rotonamic " air- and gas-cleaning panels.

" Far-Air " filters operate on the principle that airborne solids, because they have higher inertia than the air in which they are carried, will continue to travel in a straight line, while the air streams will travel by a devious route. Each filter therefore consists of alternate strips of herringbone-crimped wire cloth or gauze, sandwiched between flat (uncrimped) strips of wire gauze. These strips are 2 or 4 in. wide and are assembled into pressed metal frames of appropriate thickness, with the lengths and breadths corresponding to a range of standard sizes. An assembly of these single filters can be held in an interlocking frame and thus comprises a filter bank of large area, through which atmospheric air can be drawn by fans. Each filter is treated, before use, with a specially developed mineral oil of a specification which produces high wicking and adhesive tendencies without odour. When airborne particles, carried with the air into the filter labyrinth, impinge on the adhesive oil, they remain trapped, and the air is clean by the time it traverses the filter. A 2-in. thickness of filter is normally sufficient, the 4-in. filters being specified for those atmospheres only where the proportion of solid particles is abnormally high.

Cellulose-tissue (" paper ") filters are also available from Intermit Limited, and these can be used in conjunction with the metal fabric filters and fitted into the same frames, to give exceptionally complete removal of solids in the range up to 10 microns diameter. To protect reciprocating prime movers and air compressors against abrasion, circular filters can also be supplied; these also operate on the labyrinth principle and lengthen the life and maintain the peak performance of, for example, diesel engines both in railway and road transport use. In addition, the use of glass-fibre media, compressed on installation from 2-in. to 1-in. thick, is available, providing an effective filter for installations which must be simple to maintain and which may require different media under different operating conditions.

Fig. 1.

" Far-Air " filters can be removed and replaced in about 15 sec, and their overall efficiency is stated to be as high as 99·5%, while a conservative estimate of their life is given as 10 years. Fig. 1 shows (left) a circular " Far-Air " engine-intake filter beside a mounting adaptor and also fitted into the mounting adaptor. In addition, a standard impingement-type panel filter is illustrated (top centre), together with a standard filter frame with a high-pressure filter fitted for even finer penetration (top-right) and a rear view of a high-pressure filter fitted to a standard filter frame (bottom right).

In the " Rotonamic " air cleaner, helical blades mounted in a panel impart to the air a whirling motion in its passage through the panel. The sudden acceleration and whirling moment centrifuge solids out of the air stream into comparatively still air, where they fall out of suspension and are aspirated away for collection or other

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The 3M PG Wheel is versatile. It is available in a range of sizes to be used on all portable tools, bench machinery, stationary lathes and automatic equipment. Polishing, buffing, blending, deburring and removal of rust, scale, paint, etc., are but a few of the many operations the PG Wheel will perform quickly and economically. Such low cost, high production finishing offers a consistent, uniform finish unmatched by any other method.

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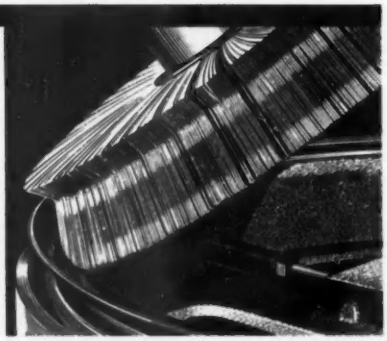


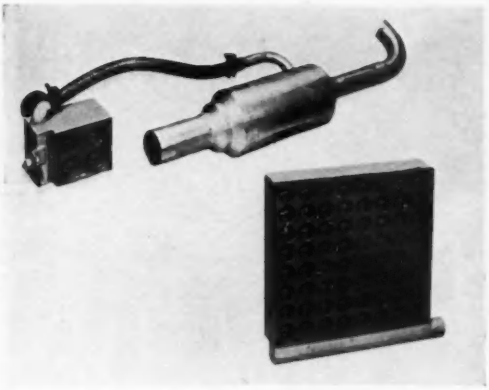


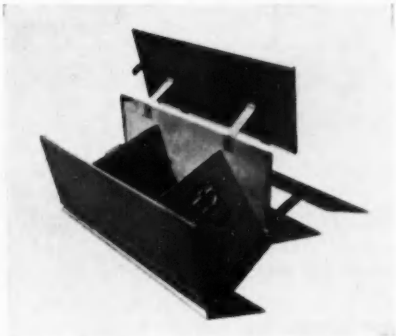
Fig. 2.

disposal. The equipment is extremely simple and has high efficiency. Furthermore, as it has no moving parts, no maintenance is required, apart from emptying the collected solids from a hopper. In many cases, these air-filtration panels can be incorporated into existing dust-removal equipment. Fig. 2 shows (top) a " Rotonamic " assembly with a flexible hose for use with an engine exhaust as a dust aspirator, and (bottom) a filter panel, the solid particles removed from air or other gases drawn through the panel being aspirated through the tubular section at the base of the panel.

Collapsible Containers

Widely used in Sweden and other European countries, " Retemba " collapsible containers are now being manufactured and distributed in Great Britain by the Warwick Production Company Ltd., of Warwick. Features of these containers include durability, low weight/volume ratio, small storage space, and rapid erection and collapsing.

The panels are constructed from a strong laminated timber, which has been specially bonded and treated to withstand rough usage and exposure in all weathers. The frame is fabricated from corrosion-resistant, fully heat-treated aluminium-alloy extrusions, with the base providing positive stacking, whether extended or collapsed.



The interior has sheer sides, free from obstructions, and all fittings, such as handles and hinges, are of cadmium-plated steel. The clasps are of spring steel, and at each end of the container is an automatic clip-fastener which incorporates a quick-release pull-toggle, permitting an effective seal. All fittings are housed in such a way as to permit the full internal capacity to be used.

At the moment, two standard sizes of container are available, i.e., model RT4, with internal measurements of 30 × 15 × 15 in. and weighing 29 lb, and model RT6, measuring 30 × 22½ × 15 in. and weighing 37 lb. The respective capacities are 3·9 and 5·8 cu ft, and in each case the container collapses to 17% of its extended volume. Special sizes can be supplied, if required.

Thread-Measuring Comparator

Based on the same principle as the " Marlco " thread-measuring parallels, but employing a dial indicator instead of a micrometer, the Marlco thread-measuring comparator announced by W. H. Marley & Co. Ltd., of London, N.11, is designed for the accurate measurement of male threads and ensures repetitive accuracy to within 0·0005 in. Although primarily intended for thread measurement, a wide range of anvils is available for other external forms, including grooves, flats, plain diameters, undercuts, and firtree serrations. The trigger mechanism to the dial indicator is easily controlled by light finger pressure, permitting engagement of the component in position before lowering the anvil.

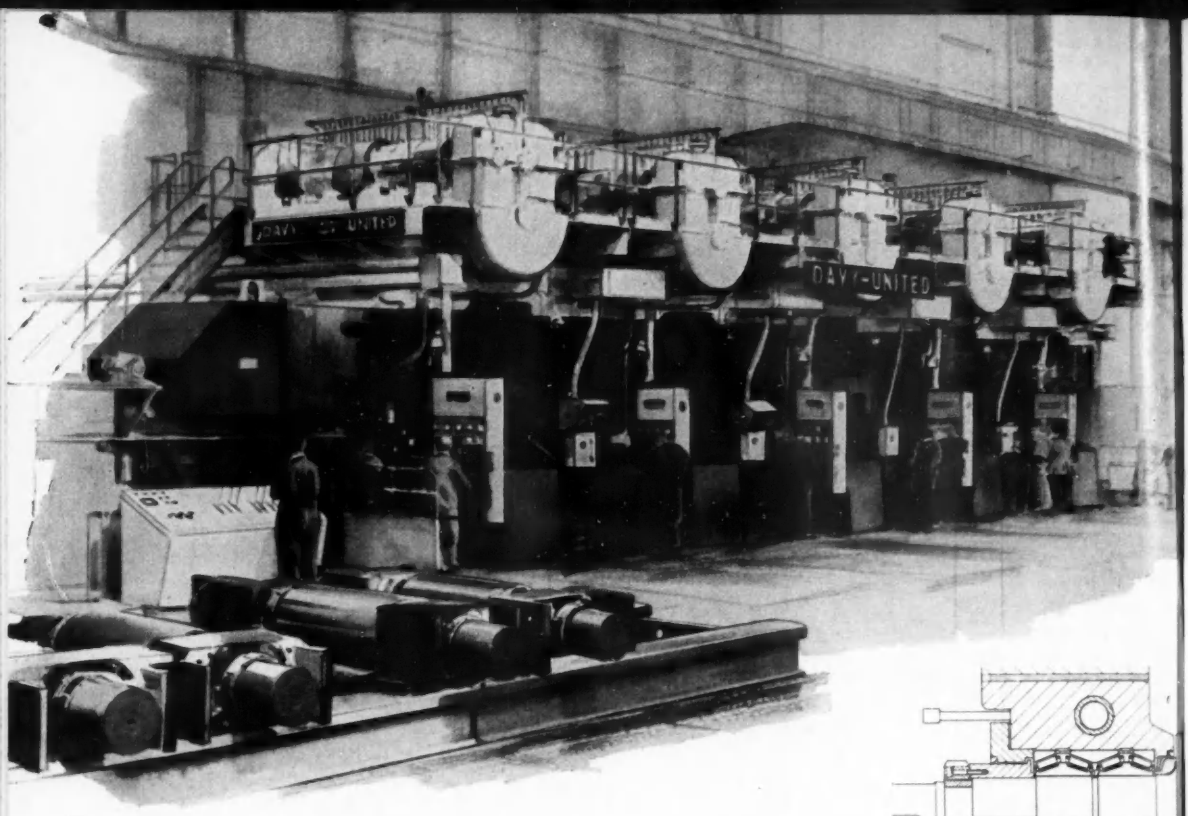
The required anvils are inserted into the holder and are retained in the axial position against a hardened ball by internal circlips, so that the anvil can be rotated to accommodate the various helix angles when measuring the effective diameter of threads. The gap is set roughly to accommodate the component, and the back-stop adjusted to register it in the desired position. As the measuring surface of the anvils is ¼ in. in width, the back-stop setting need not be accurate, visual setting being sufficient for the purpose. Final setting on the dial indicator to a zero reading is made by a fine screw adjustment through the lower anvil holder. The dial can be rotated through 360 deg. to present its most advantageous viewing position, and the instrument can be used for measurement of the effective diameters of male threads up to 2½ in. in diameter, irrespective of direction of thread.

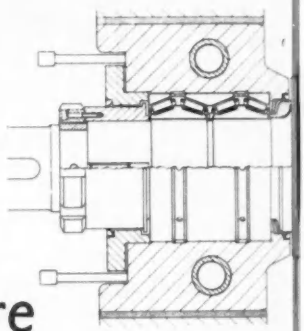
Electronic Level Controllers

Although basically operating on the capacity method, the new " Tektor Major " level controller announced by Fielden Electronics Limited, of Wythenshawe, Manchester, is not merely another form of proximity switch, but is designed for a multiplicity of level-control problems and to give stable and reliable results consistently and accurately, with virtually no attention.

A control-knob inside the case on the front of the chassis enables the set-point to be adjusted easily on site ; once adjusted, a note may be taken of the reading for future reference. The chassis can be removed quickly and easily, greatly facilitating servicing, especially when the unit is situated in comparatively inaccessible positions. The sensitivity of the instrument is better than 1·0 pF under all conditions, negligible effects arising from such factors as a ±10% change in supply voltage, ambient-temperature variations of from −20 to +50°C, and a lapse of time. There are no moving parts in the container, direct contact with the material under control is unnecessary, and installation is extremely simple.

For the high-level model, standard lengths of cable range from 6 to 35 ft maximum, and for the low-level





On the five-stand cold-reduction mill at Velindre

This five-stand cold-reduction mill built for The Steel Company of Wales, Velindre, by Davy and United Engineering Company Limited, is equipped with Timken tapered-roller bearings on the work roll necks and in the screw-down mechanism. The illustration shows the mill with spare work roll assemblies in the foreground, ready for a work-roll change-over.

The sectional drawing shows a typical arrangement of Timken tapered-roller bearings on work rolls.

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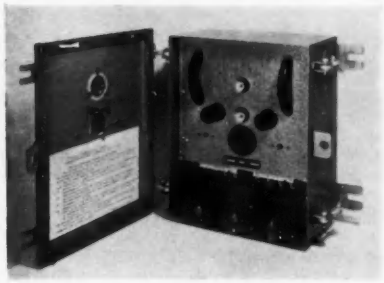


model from 6 to 20 ft. This increase in cable length is a decided advantage, inasmuch as the unit can be installed some distance away from the probe. A cable selector switch is fitted, enabling the appropriate cable length to be accommodated on site, the performance of the instrument being independent of cable length up to the stated maximum. A voltage-selector switch is also fitted, permitting the controller to be set for any supply voltage in the 110–125, 220–250, and 380–440 V ranges, 40 to 60 cps. In addition, two long-life indicator lamps are provided, one of which is on at all times, and " fail-to-safe " facilities are also included.

Thermocouple Wire

A new type of thermocouple wire announced by Philips Electrical Limited, of London, W.C.2, has been specially designed for measuring a wide range of temperatures under extreme conditions, e.g., the surface and working temperatures of all kinds of heat-treated materials, furnaces, working machine parts, and in heating and cooling installations. It is particularly suitable for use in atomic-energy plants, steel mills, mechanical engineering and motor industries, and in many other situations where an alternative temperature-measurement method would be impracticable.

Four different types are available for temperatures ranging from —200°C up to +1000°C with ceramic-packed single or double cores in metal sheathing. Diameters vary between 0·5 and 1 mm, according to type. The wire can be bent to a curve having only five times the wire diameter and into any configuration without risk of earthing or shorting the cores. It has extremely low heat capacitance at the hot junction and, therefore, a high response sensitivity. Suitable for high-pressure working conditions, it requires no additional insulation, is simple to install, and is ideal for multi-point measurement where space is limited.

Dewpoint Meter

Intended for the precision measurement of water-vapour density and pressure, proportion of water vapour by volume, and dewpoints, the Alnor dewpoint meter, originally developed by the Illinois Testing Laboratories Inc., of Chicago, is now being manufactured in the U.K. by C. F. Casella & Co. and marketed by the Electric Resistance Furnace Co. Ltd., of Weybridge, Surrey.

The instrument is portable, self-contained, and manually operated, and is designed for measuring the water-vapour content of air or any other gas with a dewpoint within the range of —80°F to room temperature. It is suitable for testing in many chemical-plant processes, plastics manufacture, and air-conditioning and refrigeration installations, and can also be employed in the measurement of furnace atmospheres for bright-annealing, carburizing, carbo-nitriding, and bright-hardening, where the water-vapour content of the furnace atmosphere and the atmosphere delivered from the gas generators is of primary importance.

The instrument operates on the principle of the cooling produced by release of pressure of a gas. By means of a built-in hand pump, a sample of the gas is drawn into the instrument and held in an observation chamber above atmospheric pressure. The temperature of the gas is then read and the pressure quickly released by depressing an operating valve, switching on a lamp and illuminating the chamber. If the gas has cooled to dewpoint owing to its rapid expansion, a fog will be observed through the window. Even where there are "no-dust " conditions, a radium foil incorporated produces ions to act as substitute nuclei, around which the droplets can form. The actual dewpoint temperature is read from a slide-rule calculator which gives the relationship between initial temperature, pressure ratio, and dewpoint.

The instrument eliminates the possibility of imprecise reading and measurement by making coolants unnecessary, and by enabling readings to be taken away from the source of the gas. It can be used, within its range, for any gas which is non-corrosive to brass or copper, and has been so designed that it can be operated accurately by semi-skilled personnel.

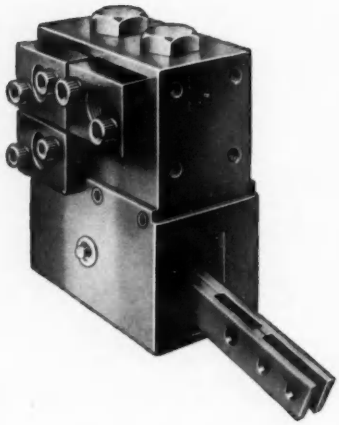
Oil-Mist Lubricators

Suitable for air pressures up to 150 psi, with flow in either direction, a new type of oil-mist lubricator developed by Telektron (Great Britain) Ltd., of London, S.W.1, incorporates a novel fixing method and has operating characteristics which are especially suitable for use in air-line systems subject to intermittent flow. These lubricators are designed to give an initial burst of rich oil-air mixture on the first flow through them, and thereafter to reduce the oil content of the mixture and maintain it at a level proportional to the flow Although they are suitable for use on constant flow, their characteristics are best suited to intermittent air-flow requirements, such as the automatic and remote control of motorized valves fitted with air-motor or cylinder units.

Fitted with gunmetal or cast-iron bodies and special transparent bowls of ½ pint capacity, held in position with a clamp ring, the lubricators are designed for simple peg-mounting from a bracket, wall, or cable tray The distance from the wall is adjustable, thus permitting a group of lubricators to be mounted close together by allowing the pipes in and out of each lubricator to pass behind the others. They are also suitable for panel-mounting and are designed so that the bowls may partially protrude through a cut-out in the panel, enabling the filling cap to be exposed With this arrangement the oil level may be easily viewed from all angles and the lubricator refilled from outside the panel. Alterations to lubricator performance are made by internal setting of the wick position in the air stream, and this cannot be altered without the use of a special spanner. The wick and peg-mounting clamp are adjusted by means of standard Allen keys. A legend strip is fitted in each bowl, indicating oil type and level.

ELLISON 'EC'

HYDRAULIC VALVES



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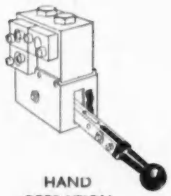
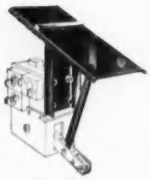
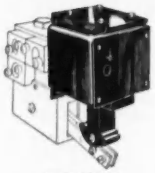


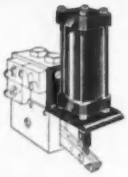
HAND OPERATION



FOOT OPERATION



SOLENOID OPERATION



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ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Mixing Processes and Flow Configurations in Two-Cycle Engine Scavenging.

By W. RIZK. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, January 31, 1958, 13 pages, 20 illustrations.)

THE performance of all two-cycle engines still depends very largely on the effectiveness of scavenging the cylinder and on the total amount of charge it is possible to achieve during the brief period available. Although the overall results of the scavenging process are of importance, insufficient emphasis has been given in the past to a detailed examination of the flow within the cylinder and at the exhaust ports. No quantitative data exist on the instantaneous composition of the flow expressed in the relative proportions of exhaust gas and scavenge air and the manner in which this ratio varies with time, as scavenging proceeds.

This paper describes work carried out at various stages between 1944 and 1954 and indicates the need for a new approach in the study of the scavenging process in two-stroke engines. Its main object is to outline various ways of studying the main features of the scavenge flow within the cylinder, as distinct from the gas dynamics of the charging process. By using a special photoelectric-cell probe in a scale model and determining the change in purity of the stream at any point, it was possible to examine the basic characteristics of scavenging flow and consider the process as taking place in broadly three phases. The first of these, entailing the formation and development of the inlet jets, has been studied in a preliminary way with the aid of a colour-reacting technique to show the mixing region, together with the undiluted core of a jet starting from rest. This has thrown light on the rate of mixing in the initial phases of scavenge flow and has indicated the possibility of achieving higher efficiencies by a reduction in the size of inlet ports and an increase in their number.

An experimental study carried out on a loop-type system has shown that the flow configuration can be substantially different from that usually assumed and that flow instabilities could occur, leading to partial short-circuiting of the flow. Photographic records of the flow and the major axis of rotation under various conditions have been obtained and assist in showing qualitatively the effect of altering the angles of entry of the jets. It is further shown that, under certain conditions, an increase in the inlet-air flow could nullify any gains in scavenging efficiency. End-to-end scavenge systems are also discussed, indicating the need for further study of some of the major parameters governing the flow.

Mechanized Surfacing with Alloy Materials.

By R. S. ZUCHOWSKI and J. H. NEELY. (From *The Welding Journal, U.S.A.*, Vol. 37, No. 1, January 1958, pp. 22–29, 19 illustrations.)

SURFACING is becoming increasingly important as a production tool. As reported some time ago, mechanized equipment is available for use with any of several processes, i.e., oxyacetylene, inert-gas tungsten-arc, inert-gas consumable-electrode, or submerged-arc. For the most part, however, the use of these processes has been restricted to applications involving only a few standard materials. Mechanized surfacing with special alloy materials has not been widespread.

There has always been a need for depositing alloy materials with one or all three of the characteristics of good abrasion resistance, high impact values, and ability to resist corrosion. To obtain deposits with these characteristics, many fabricators have had to use manual surfacing methods, because of the unavailability of some alloys in a usable form for mechanized surfacing. Recent developments have, however, extended the number and types of alloy materials which can be deposited with mechanized surfacing. As a result, fabricators are no longer limited to the use of manual surfacing, with its high cost, inconsistent quality, and low speed.

This paper focuses attention on three processes, each of which has its place as a production tool, these being (1) inert-gas tungsten-electrode hard surfacing with the addition of tungsten carbide powder, (2) the inert-gas consumable-electrode process with cold-wire addition, and (3) submerged-arc surfacing with any one of several techniques and with or without powder-alloy additions.

Each of these processes may be used to deposit a variety of materials, including alloys not available as standard welding wire. When these processes are used, better quality deposits and higher deposition rates are obtained at less cost than with other methods. The use of multiple welding wires and powder alloys furnishes a means by which the composition of alloy deposits can be altered even further to suit application requirements.

The Effects of Moisture on Transistors.

By J. T. WALLMARK and R. R. JOHNSON. (From *RCA Review, U.S.A.*, Vol. 18, No. 4, December 1957, pp. 512–524, 9 illustrations.)

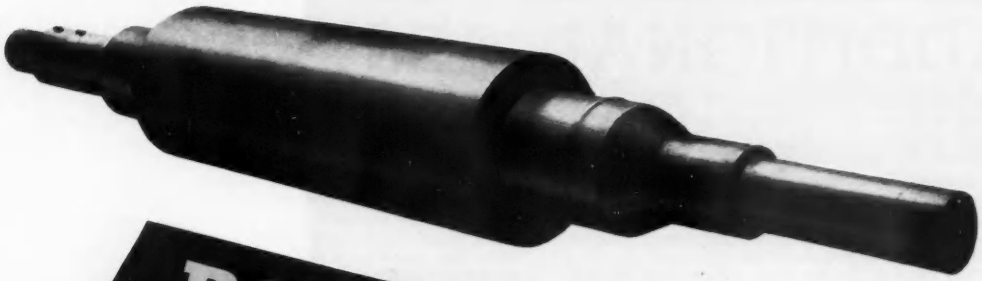
THE influence of water vapour on the characteristics of the germanium surface has long been studied in order to obtain information about the surface layer and its effects on the stability characteristics of transistors. Even minute traces of water produce such large effects that hermetic encapsulation of transistors in dry surroundings had to be introduced before their characteristics could be made reasonably stable.

It has been established that water vapour introduces a positive trapped charge on the germanium surface, driving the surface conductivity towards the *n*-type. This paper shows that at least part of this process has a long time constant (of the order of several hours). Because of the time required for the process to reach equilibrium, it has sometimes been called the " 48-hour " effect, which is present in varying degrees in most commercial transistors. It shows up as a slow change in surface potential of the germanium surface, and therefore also in the current-transfer ratio and the saturation current, when the transistor is brought from one temperature to another.

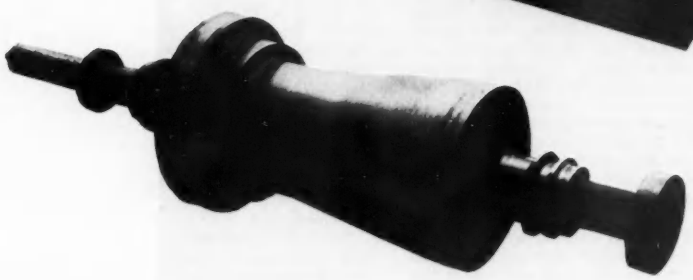
Evidence is presented to support the view that the chemical change of the surface responsible for the change in surface potential is a chemical condensation (hydration-dehydration) of the hydrous germanium oxide layer on the surface. In this process the oxide layer, when subjected to a reduction in relative humidity, gives off water slowly. Thus, new bonds, of the type Ge-O-Ge, are formed, leading to a reduction in the solubility of the oxide.

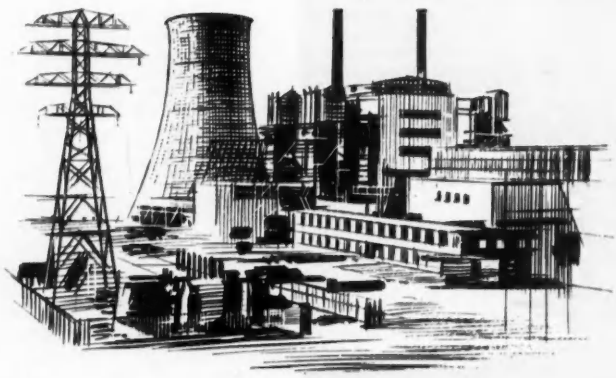
A considerable amount of data exists on the surface traps, their number, energy levels, etc. However, before the chemical-physical nature of the traps is known, it is difficult to design surface characteristics for specific device requirements. This paper points out the connection between the chemical nature of an important species of slow traps and the resulting surface potential.

Some practical consequences of the effect described



ROTOR SHAFTS





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are evident in the measurements of transistor characteristics. When a transistor has been removed from operation at a temperature above the ambient, the characteristics of the transistor will drift until the change becomes imperceptible. This is especially true when life-testing transistors, an operation which is often carried out at close to the rated maximum temperature. If the time between removal of the transistor from the high temperature and the subsequent measurement is not controlled, the measured values of current-transfer ratio and saturation current will show considerable spread, making rapid and reliable interpretation of trends difficult.

Another easily overlooked consequence is that the initial measurements on the transistor before the life test and the subsequent measurements during life are not comparable, unless allowance is made for the 48-hour effect. If this effect is not taken into account, the subsequent measurements of current-transfer ratio and saturation current will represent non-equilibrium values which are too high (or low). The usual drop in current-transfer ratio after the initial measurement, caused by progressive oxidation, is thereby masked, giving a false impression of stability.

There are two possible ways of reducing the 48-hour effect, one of which is the meticulous removal of moisture from the encapsulation and the transistor, and heating the transistor for several hours at a temperature higher than the rated temperature. The other method is to employ a getter with a water retention which is higher than that of the germanium oxide layer, even at elevated temperatures. In a practical process, a combination of the two methods may offer advantages.

As an interesting by-product of the results, the magnitude of the 48-hour effect may offer an extremely sensitive and reliable method of testing the hermetic enclosure of transistors for leaks. In this application, the 48-hour effect is considerably more sensitive than the conventional method of waiting for the reverse current-voltage characteristic to deteriorate.

Air Suspension for Road Vehicles.

By J. H. SAINSBURY. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, February 11, 1958, 12 pages, 21 illustrations.)

ALTHOUGH several patents have been granted since 1906 for designs using air as a suspension medium for both passenger and commercial vehicles, it was not until the early 1930's that it was given serious consideration. In January 1936, the results of an investigation into the application of air springs to a passenger car were published. It is interesting to note that, in this instance, two-convolution springs were used as suspension units, and that the same type is currently in use in the U.S.A. on long-distance passenger coaches. In this connection, two-convolution circular springs have the advantages of providing the most compact shape for a given volume and of lending themselves readily to mass production. In addition, their circular shape makes it possible to maintain a uniform cross-section, which is considered desirable for good flexing life.

It is only in recent years, however, that any enthusiasm has been aroused in the automobile industry regarding the application of air springs to vehicles, although experience in the U.S.A. over the past seven years, particularly on long-distance coaches, seems to have established air springs as an improved method of suspension.

This paper presents a résumé of the course of development of air springs of the double-convoluted and rolling-lobe types. The theory of air-spring design is discussed and typical methods of installation are described. Present-day air springs are limited to a maximum pressure of 100 psi to cater for the maximum static load. There are no minimum pressure requirements for a double-convolution bellows but, in order to obtain good flexing life and maximum spring response, the rolling-lobe type is generally limited to a minimum pressure of 40 psi. In addition, the ancillary equipment for an air-suspension system is described, this consisting of compressor, storage tank, and levelling valves.

It is considered that the advantages of air suspension will eventually lead to its general adoption. With its introduction into passenger-car suspension, it is possible that tyres will be put to their correct use, i.e., to provide traction. At the moment, pneumatic tyres also provide an important part of the suspension of the vehicle and are, in fact, themselves a type of air suspension. This is the main reason for operating pressures of about 24 psi. With the introduction of air springs, it is possible that higher tyre pressures will be used. Another possible outcome of air-suspension systems in passenger cars is the additional use of the necessary air compressor for driving existing auxiliaries, e.g., windscreen-wipers. It is believed that a compressor with a capacity of about 0·5 cfm at a pressure of 120 psi will be suitable for the suspension system.

Extension of the Theory of the Optimum Burning Programme for the Level Flight of a Rocket-Powered Aircraft.

By A. MIELE. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 24, No. 12, December 1957, pp. 874–884, 9 illustrations.)

CONSIDERABLE attention has been devoted in recent years to the theory of optimum performance of aircraft and missiles. The classical quasi-steady approach, widely used in the performance analysis of conventional aircraft, has been frequently replaced by more modern and significant methods which take into consideration the inertia terms.

In this paper, the optimum burning programme for the horizontal flight of a rocket-powered aircraft is analysed and discussed, and the results of previous theories are extended to cover the general problem of minimizing an arbitrary function of the final values of time, mass, distance, and velocity. By using the indirect methods of the calculus of variations, it is shown that the totality of extremal arcs is composed of zero-thrust sub-arcs, sub-arcs to be flown with maximum engine output, and variable-thrust sub-arcs. For the latter, a closed solution is obtained.

Particular problems, such as maximum range, maximum endurance, minimum propellant consumption, and maximum velocity increase, are treated within the general frame of the present theory for various types of boundary conditions.

Detailed attention is devoted to the thrust programming which maximizes the range for the case where the overall flying time is prescribed. A method for constructing extremal paths is supplied under the assumption of a parabolic drag polar having either constant coefficients or coefficients depending on the Mach number.

An important difficulty associated with the linear aspect of the present problem is constituted by the fact that the Legendre-Clebsch condition fails to yield any information on the minimum or maximum character of the Eulerian paths. Moreover, the Weierstrassian function is zero at all points of the variable-thrust sub-arc. This difficulty is overcome with a generalization of a previous method of the same author, based on the use of Green's theorem.

Unsteady-State Heat Transfer to and from Gases in Laminar Flow.

By T. D. PATTEN. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, January 1958, 17 pages, 18 illustrations.)

THE regenerative heat-exchanger is a practical example of unsteady-state heat transfer. Heat is stored in a passage wall or a matrix, and this heat is transferred to air which enters the passage with a temperature which is constant, or nearly so, with respect to time. Therefore, as the air, initially cold, passes through the passage, the air will be heated and the wall will be cooled. The temperatures of both substances at any one cross-section will vary con-

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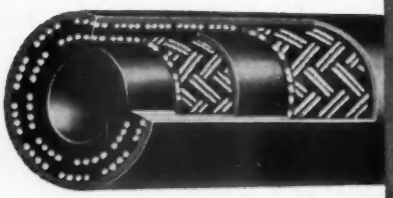
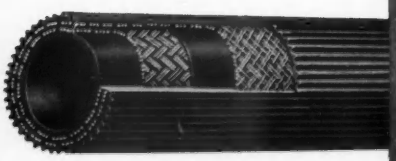


STYLE A *for service where oil mist may be present in the line, and where operating pressures up to 325 lbs. per sq. in. are used.*



STYLE B *for general, light and medium pneumatic tool service and working pressures up to 210 lbs. per sq. in.*

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tinuously with time and the process is therefore described as " unsteady-state ". There are two distinct operations in the regenerator, one in which the wall is heated by a supply of hot gas which is itself cooled, and that of the succeeding period, in which the wall is cooled, owing to the passage of cold air. These two separate phases may not, at first sight, be expected to possess similar heat-transfer properties.

Some experimental values of heat-transfer coefficient for the unsteady-state case and for square, triangular, and other non-circular cross-section passages have been obtained by various investigators.

Because the circular cross-section is often considered as the fundamental passage in heat-transfer forced-convection work, it was decided to investigate this case. In this paper are described unsteady-state heat-transfer experiments in which a gas (air) flows vertically upwards in forced-convection laminar flow through a tube of circular cross-section. By means of an analytical solution, experimental heat-transfer coefficients have been obtained. These results, when presented graphically, are compared with theoretical heat-transfer coefficients for steady-state heat-transfer predicted for the same physical arrangement and for prescribed conditions of tube-wall temperature. The works on which these steady-state heat-transfer coefficients are based are summarized, and experiments are described in which the apparatus is operated as a parallel-flow regenerative heat-exchanger, the unsteady-state heat-transfer coefficients obtained in this way being compared with those unsteady-state values for single-blow operation.

Because of the magnitude of heat losses at lower values, the investigation has been confined to values of Reynolds number between 1000 and 2500. Within this range, at moderate temperature differences, the processes of heating and cooling of gases reveal similar heat-transfer properties. When the tube-wall temperature is either constant or has a uniform temperature gradient, it is shown that the Nusselt number is in agreement with that predicted for steady-state heat transfer for the same wall-temperature distribution.

The investigation deals with single-cycle operation, in which the supply is either hot or cold, and with cyclic operation as a parallel flow regenerator. Heat-transfer coefficients obtained from the cyclic operation tests are of the same order as those from the single-blow tests. An analytical expression for the prediction of outlet temperatures, assuming a varying supply-inlet temperature and non-uniform initial wall temperature, is presented, and this expression is used in the calculation of the single-blow results obtained.

Journal-Bearing Performance for Combinations of Steady, Fundamental, and Harmonic Components of Load.

By G. S. A. SHAWKI. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, January 1958, 11 pages, 17 illustrations.)

THE research described in this paper has been planned and carried out to investigate the performance of a complete journal bearing for load waves composed of steady, fundamental, and harmonic components of load.

As described in this paper, the performance characteristics of the test bearing have been studied for some forty different modes of loading. Steady and transient whirls of the journal centre under approximate no-load conditions are obtained, and various damping influences on the journal oscillations are pointed out. The frequency of whirl is found to assume a value between 0·49 and 0·50 of the journal rotational frequency.

The fundamental case of a unidirectional sinusoidal load is investigated in some detail. Test results show that the speed ratio ω_1/ω is a prime factor in the bearing behaviour, and that values of this ratio slightly less than 0·5 give rise to critical changes in the bearing performance of a character mainly dependent on the ratio of the fundamental to steady components of load.

An interesting phenomenon starts to appear with low-amplitude harmonics, i.e., the appearance of secondary critical changes in the performance at submultiples of the one-half speed ratio, i.e., at ω_1/ω slightly less than 0·25, 0·167, and 0·125 for second, third, and fourth superposed harmonic components of load.

For medium- and high-amplitude second and third harmonics, test results clearly show the existence of two distinct critical values of the speed ratio, the first corresponding to the harmonic component, while the second corresponds to the fundamental component. With increasing values of the amplitude ratio, the first critical speed ratio becomes more and more significant, with relative changes in performance characteristics appearing, of nearly the same order at the two critical ratios for medium amplitudes. An inverted situation is obtained with high-amplitude ratios.

The phenomena of journal centre whirl encountered in the tests are explained in the light of the theory of vibrations; results suggest that the behaviour of the bearing vibrational system seems to be qualitatively similar to that of a linear system. In addition, the analysis is extended to include the case of a variable load on a uniformly rotating journal.

Cavity Formation in Iron Oxide.

By D. W. JUENKER, R. A. MEUSSNER, and C. E. BIRCHENALL. (From *Corrosion*, U.S.A., Vol. 14, No. 1, January 1958, pp. 57–64, 14 illustrations.)

AT temperatures above approximately 600°C, iron is capable of forming three stable oxides, i.e., wüstite (FeO), magnetite (Fe_3O_4), and hematite (Fe_2O_3). Wüstite, which has a stoichiometric deficit of iron throughout its broad composition range and is unstable at low temperatures, ordinarily is the major constituent of the high-temperature oxide scale. Detailed investigations of the growth mechanisms of the three phases and of the transport characteristics of their components have been carried out by various investigators, and it appears that practically all of the material transport responsible for the growth of wüstite, and probably of magnetite as well, is the self-diffusion of iron in the oxide lattice.

Some research activities by the present authors have been directed towards an improvement in the accuracy of determination of the rate of growth of magnetite on the lower oxide. In the course of this programme, attempts were made to grow suitable wüstite specimens from pure iron by direct oxidation in an oxygen atmosphere. The occurrence of an unexpected set of phenomena at this stage of the experiment has led to the study which is the subject of the present paper.

In general, the aim of this work is a qualitative investigation of the oxidation of iron in pure oxygen at temperatures between 700 and 1000°C. Under these conditions, all three oxide phases normally are present. The progressive diminution of the iron core due to the outward migration through the oxide lattice results in stresses throughout the sample. Unless the oxide scale is sufficiently plastic to follow the recession of its iron foundation, these stresses must be relieved by internal fracture of the oxide or by separation, at least locally, of the scale from the iron. The continued oxidation following the latter type of separation is the particular object of the present paper.

As described, a study has been made of the deep oxidation of iron at high temperatures and in an oxygen atmosphere. Large cavities are always found in specimens whose total oxygen content has been brought to that of FeO. The scale thickness of such specimens, together with other evidence, implies that FeO is plastic in the temperature range in which it is stable, while one or both of the higher oxides is relatively rigid. Evidence is presented which indicates that iron is transported to its surrounding scale with little or no body diffusion path; the mechanism involved is not identified. An expression, analogous with the parabolic rate law for scaling of plane specimens, is developed for application to cylindrical geometry.

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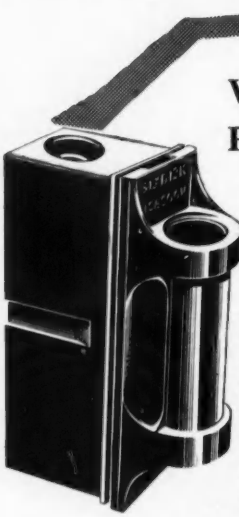

The fuse shown left is typical of the Slydlok 'H' range and is available in 5, 15 or 30amp ratings

An exploded view is shown on right. This fuse enables the employment of either H.R.C Cartridges or semi-enclosed fuse-links, as illustrated.

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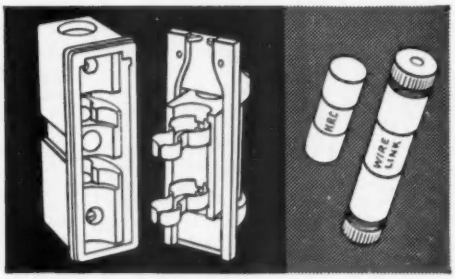
The Slydlock series of fuse units are vibration proof—which means they have been extensively tested for use under the most arduous working conditions. This is but one example of the technical progress made by Wilcox in the design and manufacture of fuses over the past 30 years.



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brake are of improved construction, with the flywheel mounted on a quill rigidly attached to the frame, removing flywheel load from the drive-shaft. The slide adjustment is motor-driven.

The automatic circulating oil pressure lubrication system features double-micronic filtration to ensure cleaner oil, longer lubricant life, and less frequent oil changes. The sump, the oil-pump motor and pump, and the filters are all contained in the press bed, and all points are assured proper lubrication, faulty lubrication being guarded against by special safety switches.

All controls are built into the press frame for easy access and safety and for " plug-in " installation. Controls for all auxiliary mechanical devices are provided and can be adjusted at floor level. Control features include die safety-blocks, adjustable control arms, recessed auxiliary power outlets, eight auxiliary air outlets, a solenoid air valve for the flywheel brake, die-space lights, and compact air-pressure manifolding.

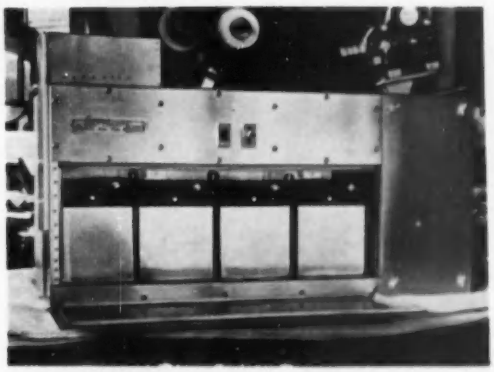
HIGH-SPEED AUTOMATIC PROCESSING EQUIPMENT FOR 16-MM FILMS

Suitable for a wide range of industrial and other applications, such as high-speed motion pictures, oscilloscope records, gun-camera and missile films, and television news films, where viewing of the film may be desirable as soon as possible after the recorded event has taken place, the new " Mini-Rapid 16 " automatic processing equipment for 16-mm films announced by the Fairchild Camera and Instrument Corporation, of Syasset, Long Island, N.Y. is capable of developing, fixing, and drying an ordinary 100-ft roll of black-and-white film ready for projection within 20 min after taking the picture. Weighing only 70 lb dry and measuring 27 × 12 × 13 in. high, the equipment is also suitable for airborne operations.

The major elements in the equipment are easily interchangeable film-transport plastic inserts containing a high-speed developer, a rapid fixer, a hypo-eliminating agent, and a static rinse, though provision has also been made, in the case of the latter, for the use of an accessory tank for circulating water. The resulting film is of commercial quality but a more permanent quality can easily be obtained by running the film through a second time, with the tanks filled only with water. A wide-range capacity in film length and longevity of chemical solutions are also features of this equipment, and lengths as little as 1 ft or as much as 400 ft can be processed without the need to change or replenish the chemical solutions. Construction is of welded stainless steel, with an aluminium rear housing. All chemical tanks, which each hold 18 oz of liquid, are easily removable for cleaning and renewal of solutions. All compartments are accessible for cleaning and wiping by hand, and the unit can be placed on a table top for operation.

Manual operation of the unit begins with placing the exposed 16-mm film in the film compartment. After insertion of the film into the entry port, with the emulsion side down, the film supply compartment is closed, and the film automatically threads itself through the equipment to the take-up compartment, corresponding to a length of about 80 in.

Rubber rollers on the plastic insert assembly serve a triple function, i.e., as drive rollers for film transport, as a means of agitation, and for squeegeeing the exhausted solution back into the solution container, thus reducing solution carry-over from one tank to another. The rollers are on floating shafts retained against the driven centre-drum by means of an elastic member. The film is guided in its path by grooves in the sides of the plastic inserts. Once the film passes between the rubber rollers and the centre-drum it is automatically transported to the next rubber roller and on through each insert. Drying of the film is effected by a high-velocity jet of heated air on the emulsion side of the film. The base side of the film is held against a driven fabric belt by means of the air blower which assists in the transport of the film on the drier. Take-up is accomplished by attaching the leading edge of the processed film to a standard daylight-loading spool and dropping the spool into the take-up compartment, where it rides on a rubber-covered film spool which is slightly over-driven. This method takes up the film firmly and ready for projection.



A variable-speed film-drive system makes it possible to adjust the rate of processing for over and underexposed and/or temperature variations, the normal complete processing rate being about 6 fpm, with a maximum of 10 fpm. The film may be checked for degree of development at the take-up spool and the speed adjusted to compensate for any errors in exposure. Thus, the control may be used to pre-select a specified degree of development when all the other factors are known.

COMBINED ELECTRONIC PRESSURE INDICATOR AND ENGINE ANALYSER

Utilizing an electrostatic principle for making precision dynamic measurements, the Kistler SLM engine indicator-analyser, introduced by the Kistler Instrument Corporation, of North Tonawanda, New York, is designed for efficient trouble-shooting, monitoring, and adjusting of modern high-speed, high-compression engines. Cylinder, manifold, fuel-injection, and detona-

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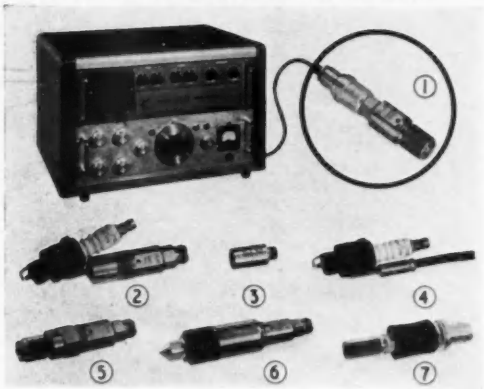
tion pressures, combustion-pressure rates, engine vibrations, and crankshaft torsional vibration can be shown and accurately measured. In addition, this combined pressure indicator and analyser can be used to adjust timing and to check peak cylinder pressures, load distribution, valve operation, pre-ignition, and knock.



The instrument makes use of a special Swiss-made quartz-crystal pressure-gauge which, when used with various accessories and adaptors, provides a visual display of the required engine functions on a standard oscilloscope screen all components being simple, rugged, and well-suited to shop and field applications. When used to measure cylinder pressures, the pressure gauge is mounted in a modified spark-plug, in a special indicator port, or in place of the fuel injector, and will withstand combustion-gas temperatures up to 3200°F without special air or water cooling. A selector switch permits the choice of the signal from any one of sixteen pressure gauges or vibration pick-ups. As many as four signals can be superimposed on the screen, making possible, for example, the simultaneous display of peak pressures in four cylinders for load-balancing adjustment.

In operation, as the crankshaft of the engine revolves, a dot moves horizontally across the oscilloscope screen at a constant speed. A signal from the pressure gauge causes the dot to move upward as well. Thus, the instantaneous vertical position of the dot represents the pressure, and its instantaneous horizontal location represents the crankshaft position. With each complete revolution of the crankshaft, an electrical pulse is generated which causes the dot to return quickly to its starting position for the next journey across the screen. Pressure measurements are made by simply turning a dial reading directly in pounds per square inch pressure. By means of a piston displacement pick-up, the dot can be driven to move horizontally back and forth across the screen as the piston moves up and down. The pressure signal causes the dot to move up and down, resulting in a traditional indicator card or pressure-volume diagram. Any portion of an overall engine diagram can be magnified as much as a thousand times by simply switching the instrument to a more sensitive range, permitting detailed study of significant phenomena in the diagram, e.g., valve-opening and scavenging pressures. Pressure and vibration patterns for normal operations are generally measured, photographed, and used as samples. Subsequent deviations caused by faulty operation can be easily detected.

Available in three models, i.e., marine-industrial, automotive, and laboratory, the instrument includes an amplifier-calibrator, oscilloscope, and selector switch housed in a compact, portable case, as shown in the illustration, plus several high-precision pressure-gauges, pick-ups, and connecting cables. As requirements increase, this equipment can be expanded to include adaptors and accessories most suitable for a particular application. The illustration also shows some of the range of pressure-gauges and pick-ups available, i.e., (1) the PG-14 cylinder-pressure gauge, (2) the SA-14 spark-plug adaptor with the PG-14 pressure gauge, (3) the PG-6 miniature engine-pressure gauge, (4) the SA-6 spark-plug adaptor with the PG-6 pressure gauge, (5) the fuel-injection pressure gauge, (6) the vibration pick-up, and (7) the sync-pulse pick-up (magnetic, mechanical, or photo-electric type).

PRECISION VACUUM OVEN

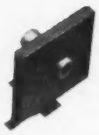
The Gardiner precision vacuum oven, announced by Griffin & George Limited, of Alperton, Wembley, is a symmetrical vacuum drying oven of circular plan, with a large heat capacity and uniform temperature distribution ; although originally designed for drying sugar syrups and molasses and for providing a standard reference method for determining the moisture content of sugar products, it can be used with many other materials, particularly of a labile nature, whenever exact and reproducible results of experiments on drying losses are required.

In the new oven, the sample is taken into solution and is distributed over an aluminium powder extender contained in a sample dish. It is then heated in a vacuum, while a current of air or inert gas, dried to a water content not exceeding 0·0007 milligram/litre, is bled over its surface. The air-bleed drying train comprises three 6 × ¾ in. glass U-tubes, filled with activated alumina, on the inner face of the door, and a glass tube, 9 × 2 in. in diameter, filled with barium oxide and positioned horizontally in the case.

Measuring 17½ × 17 × 12½ in., the oven is fitted with a cadmium-plated mild-steel heating block, 9 in. in diameter by 1¼ in. thick, heated by twelve refractory heating elements, inserted radially and penetrating to near the centre. The block also has two annular grooves, one for locating an O-ring seal, and the other for accommodating six shallow sample dishes, each 2 in. in diameter. Pockets are provided for a thermometer and thermostat. Around the perimeter are six air entry ports, connected to a tubular distribution ring, the ports being inclined at 45 deg. to project the air up against the oven lid immediately above the sample dishes, whence it passes continuously over the surface of the sample and then through exit ducts in the lid into a metal desiccator. Two-heat switching permits 70- or 160-W loads to be selected, with symmetrical heat distribution in both cases. The air flow to the chamber can be controlled and measured between 0·5 and 100 millilitres/min by means of a soap-film flowmeter.

The control panel is mounted on one side of the case and contains the air and vacuum control valves, vacuum gauge, control switches, fuses, and mains and thermostat indicating lights.

Illustrating the extreme hardness of SINTOX Industrial Ceramic, the photograph on the right shows a ¼" dia. tube of SINTOX which, without even chipping, was forced through ¼" thick mild steel plate.



SINTOX IN ENGINEERING

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The many mechanical applications of SINTOX industrial ceramic will be of immense interest to the designer and mechanical engineer. The remarkable resistance to abrasion of SINTOX makes it particularly suitable for such uses as inserts and supports at points where rapid wear presents a problem. Already it has made a name for itself in the Textile industry, where the advent of artificial fibres brought entirely new problems. Thread guides made of SINTOX have been proved to have up to a hundred times the life of those made of hardened steel.

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NEWS OF THE MONTH

PERSONAL

Edgar Allan & Co. Ltd. announce the appointment, as from January 1st, 1958, of **Dr. A. D. Merriman, G.C., O.B.E., D.L., M.A., M.Ed., D.Sc., C.I.Mech.E., F.R.S.E.,** formerly Secretary of the Institution of Metallurgists, as Consultant on scientific projects.

Mr. Spence Sanders has resigned the chairmanship of the Fulmer Research Institute on his retirement from the board of directors of Almin Ltd. His place as chairman has been taken by **Mr. W. R. Merton. Mr. J. G. Graham** has been appointed to the board of directors.

Mr. A. D. Zemenides, B.Sc. (Eng.), formerly with G.E.C. Coventry, has been appointed technical manager of G. A. Stanley Palmer Limited, of London, W.C.2.

Mr. J. A. C. Williams, M.Sc., A.M.I.Mech.E., A.F.R.Ae.S., A.B.Ps.S., has been appointed principal of the College of Aeronautical and Automobile Engineering, Chelsea.

Mr. K. G. Lampson, Lt-Col. P. F. Benton Jones, and **Lt-Commander G. W. Wells** have been appointed directors of Steel, Peech and Tozer and Workington Iron and Steel Company, two branches of The United Steel Companies, Limited. Lt-Col. Benton Jones has also been appointed a director of the Beckermet Mining Company, Limited.

Mr. J. Driscoll has been appointed sales manager, and **Mr. F. V. M. Morgan** contracts manager, of the English Electric Company's Diesel Engine Division at Brownsover Hall, Rugby.

Mr. David H. Bramley, M.I.Mech.E., head of the Department of Industrial Administration at the College of Technology, Birmingham, has joined the board of Geo. Salter & Co., Ltd., of West Bromwich.

Mr. A. F. Appleton, formerly head of the Electronics and Vibration Laboratory of Bristol Aircraft Ltd., has taken up an appointment as chief engineer with Benson-Lehner (G.B.) Ltd., of Southampton.

Mr. R. J. Kingsnorth, M.I.E.E., A.M.I.Mech.E., has recently been appointed manager of the Process Control Division of Elliott Brothers (London) Limited, a member of the Elliott-Automation Group.

Mr. T. E. Potts has been appointed a managing director of the British Oxygen Company Limited.

Mr. A. H. Shaw, M.B.E., traction-battery sales manager of Crompton Parkinson Ltd., has been appointed to the Executive and Finance Committee of the Electric Vehicle Association of Great Britain.

Mr. G. E. Liardet becomes chairman and managing director of the recently formed Simms Motor & Electronics Corporation Limited and relinquishes his position as managing director of Simms Motor Units Limited, though retaining the chairmanship of the board. In turn, **Mr. J. Ayres** is appointed managing director of Simms Motor Units Limited.

Dowty Group Limited announce the appointment of **Mr. S. Hinchliff** to the board of Dowty Seals Limited; Mr. Hinchliff is also production manager.

Mr. W. Dalziel, production manager of the Electronic and Equipment group, and **Mr. H. Fox Wright,** contract manager, have been appointed executive directors of The Plessey Co. Ltd., of Ilford, Essex.

Mr. D. L. Campbell has been appointed managing director (sales) of the Metallurgical Equipment Export Company Ltd., of London, S.W.1, a consortium of leading companies engaged in the manufacture of steelworks plant.

Mr. P. K. Hart has been appointed to the board of Qualters & Smith Bros. Ltd., and **Mr. J. Dunkerley** to the board of Henry Broadbent Ltd. Both these companies are subsidiaries of Kerry's (Great Britain) Ltd.

Mr. W. E. Wright, F.C.S. retired on December 31st, 1957, from the board of directors of the Pyrene Company Limited and from control of the Metal Finishing Division. **Mr. H. F. Parshall, M.A., T.D.,** who has been on the board of the company since 1947, now takes over board responsibility for the Metal Finishing Division.

Mr. J. Allan Perham, who has been Sales Director of the Atlas Copco Group for the past two years, has been appointed Resident Director of the Atlas Copco companies in the U.S.A. Based at New York, he will be responsible primarily for the co-ordination of the group's sales programme in the United States. **Mr. Erik Johnsson** succeeds Mr. Perham as Sales Director. He was appointed Managing Director of Atlas Copco (Great Britain) Ltd. in 1949, when he was responsible for introducing the " Swedish Method " into the U.K.

Mr. A. J. Beanland, B.Sc.Tech., M.I.E.E., A.M.I.Prod.E., Fellow A.M.E.M.E., has been appointed Group Sales Director of the Lancashire Dynamo Group. Mr. Beanland, who will be a director of Lancashire Dynamo Group Sales Ltd., will be in charge of Group Sales organization both in the U.K. and overseas.

Mr. J. W. MacMahon has been appointed general manager of the Industrial Lubricants Division of Wakefield-Dick Industrial Oils Ltd., in succession to **Mr. R. J. Turner,** who has retired. Mr. MacMahon has also been appointed to the board of directors of the company. **Mr. C. R. Woodfield,** works production manager for the Wakefield Group, has also joined the Wakefield-Dick board.

Lt. COLONEL F. W. FOSTER, M.C., A.M.I.E.E.

It is with regret that we announce the death of **Lt. Colonel F. W. Foster, M.C., A.M.I.E.E.,** at the age of 82 at his home in Marple, Cheshire. Colonel Foster, who was a noted member of the electrical industry, joined George Ellison Limited in 1924 and was for twenty years manager of their Manchester and District Sales Office, after which he served the Head Office in a consultative capacity, retiring in 1947.

MR. C. SLYMON

We regret to announce the sudden death, on January 18, 1958, of **Mr. C. Slymon,** sales manager of the Friction Materials (Automotive) Division of Small & Parkes Ltd., of Manchester.

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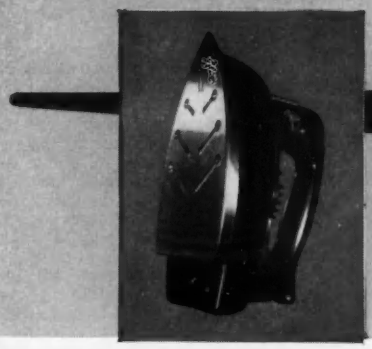

In the Hoover steam-or-dry iron is a spring-loaded gasket which acts as a seal against leakage. This gasket, only $\frac{1}{32}$" thick, was moulded by the Dunlop Rubber Company, from I.C.I. silicone rubber. I.C.I. silicone rubber retains its flexibility, without deterioration, at temperatures exceeding 250°C or 480°F.

I.C.I. silicone rubbers are also finding increasing uses in the aircraft industry. Modern flight requires materials that will stand up to the extremes of high and low temperature encountered. And here I.C.I. silicone rubber, unaffected by temperatures from −80°C to over 250°C is proving the answer to many a designer's prayer.

Hot or cold, there's always a job for I.C.I. silicone rubber

I.C.I. SILICONE RUBBERS —material progress

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ICI

ICS-47

BUSINESS NOTES

The rapid expansion of the company's activities overseas has made it necessary for **Evershed & Vignoles Limited** to open a branch office at 142 Rue Gallait, Brussels, Belgium. This office, to be opened on April 1, 1958, will be under the management of Mr. C. Samyn, who has for a number of years handled the company's products in Belgium. The whole range of electrical instruments, and instrumentation and control equipment will be made available through this office to Belgium, the Belgian Congo, and Luxemburg.

Rhodes, Brydon & Youatt Ltd., of Stockport, Cheshire, centrifugal-pump manufacturers, have acquired the whole issued share capital of **Furnival & Co. Ltd.,** of Reddish, Stockport, who specialize in the manufacture of machinery for the printing and allied industries.

At the annual general meeting of **Central Tool & Equipment Co., Ltd.,** it was decided to shorten the name of the company, with effect from January 1958, to **Centec Machine Tools Ltd.** There will be no change insofar as the management or control of the company or its products is concerned.

The first full-scale production unit in India to specialize in the field of compressed air will be operated by the **Consolidated Pneumatic Tool Company India (Private) Limited,** a subsidiary of the **Consolidated Pneumatic Tool Co. Ltd.,** of London. Equipment for the new factory, which will be located at Muland, near Bombay, and which is expected to be completed about the middle of this year, will comprise the latest types of machine tools, together with an extensive range of inspection and test equipment.

Schlegel regenerators for re-refining used oils, manufactured in Germany by **Schlegel Brothers,** of Stuttgart, are now available in the U.K. and Eire from **Liquid Systems Ltd.,** Norwich Union House, Wellesley Road, Croydon. These regenerators, which combine distillation, adsorption, and filtration, operate on a physical-chemical principle, and can also be used for petrol, kerosene, turpentine, nitro-solvents, trichlorethylene, etc.

Following the recent acquisition by **Simms Motor Units Ltd.** of the **Motor & Electronics Corporation,** considerable changes are proposed in the structure of the group, which now consists of fourteen operating companies and one associated company. A diversity of interests is covered, including fuel-injection equipment, electrical apparatus, turbochargers, general engineering, ventilating and heating, plastics, oil burners, domestic products, electronic components, switch-gear, radio, television and radar accessories, and vacuum ware.

At an extraordinary general meeting of shareholders held on December 31, 1957, approval was given to change the name of Simms Motor Units Ltd. to **Simms Motor and Electronics Corporation Limited,** which becomes a holding company and will be responsible for co-ordinating the activities of the operating companies and the general planning and supervision of group policy.

Simms Motor Units Ltd. is now one of the eight operating companies comprising the Simms Group, the other companies in the group being Horstmann Ltd., Hadrill & Horstmann Ltd., Industrial Fan & Heater Co. Ltd., Simplus Products Ltd., Clearex Products Ltd., R. F. Landon & Partners Ltd., and Mono-Cam Ltd.

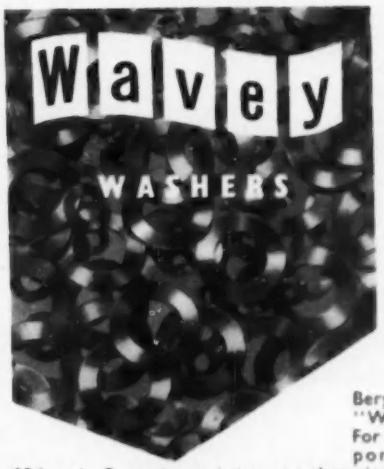
The Motor & Electronics Corporation Ltd. group of companies will consist of M.E.C. Ltd., N.S.F. Ltd., British Vacuum Flask Co. Ltd., Remax Ltd., Lester Plastics Ltd., A. R. Parsons & Co. Ltd., and Thompson Manufacturing Co. Ltd.

Each operating company will be autonomous and will retain its representatives of the parent company on the board.

Durham Raw Materials Limited, of 1/4 Great Tower Street, London, E.C.3, and **J. M. Huber Limited,** of 6 Great Winchester Street, London, E.C.2, announce that, as from January 1, 1958, Durham Raw Materials Limited have been appointed distributors in the United Kingdom of materials manufactured by the **J. M. Huber Corporation,** 100 Park Avenue, New York 17. In addition to their carbon blacks, these materials include " Zeolex " (an aluminium silicate reinforcing agent), " Turgum S ", " Butac", and " Nutac ", which are rubber rosins with specific uses, " Actone ", (an activator/accelerator), and a range of hard clays of which there are no British equivalents. J. M. Huber Limited will process all orders already received and contracted for, but Durham Raw Materials Limited will deal with all those placed subsequent to January 1, 1958.

The **Olin Mathieson Chemical Corporation** and the **Cuno Engineering Corporation** have announced their association in a jointly owned company, the **Olin Cuno Filter Corporation, U.S.A.,** for the manufacture and sale of " Micro-Klean " filters outside the United States. It is stated that the decision to create the new company follows extensive surveys of the European economy, which has indicated a widespread need for industrial filters of this type.

An agreement has been signed between **Elliott Brothers (London) Ltd.,** of Lewisham, and the Holtzer-Cabot Motor Division of the **National Pneumatic Co. Inc.,** of Boston, Mass., for the manufacture of many of the Holtzer-Cabot instrument motors in the Elliott Brothers factory in England. The motors to be manufactured, to meet the special requirements of European and British markets, are of the precision electric servo-motor type for strip recording instruments, timing devices, and electronic control systems.



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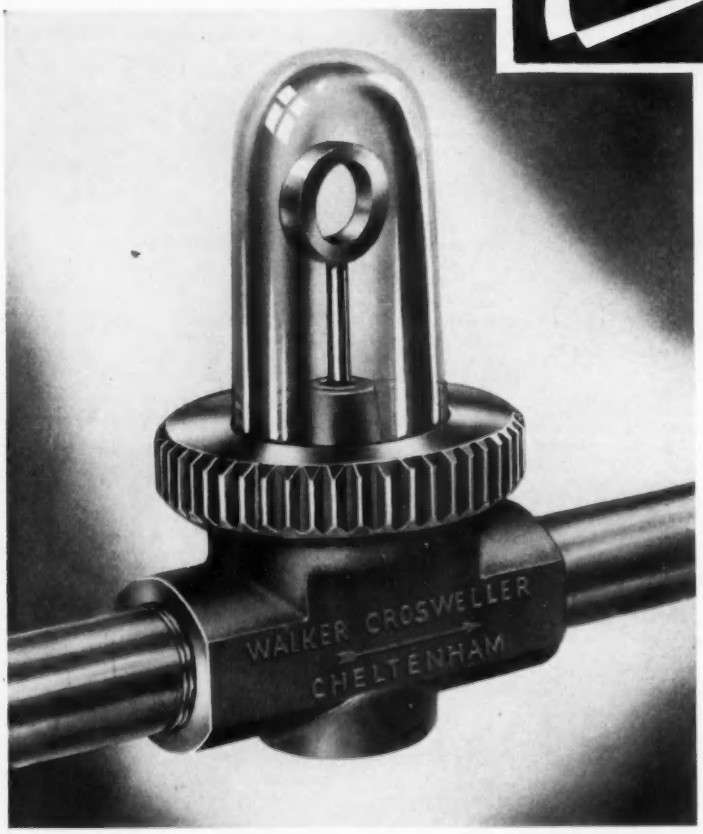

. . . with the adjustable flow range — easily set for high or low rates of flow.

A simple but reliable indicator which shows at a glance whether flow is taking place. The liquid, as it passes, spins a chromium plated ring under a glass dome. If the flow stops, the ring stops spinning and warns you the liquid is not circulating. The movement is so decided that it can be clearly seen from a distance, even in a bad light—no peering into dark corners or climbing into awkward positions.

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Effective from January 1, 1958, **Birfield Industries Limited,** Sales Organization of the **Birfield Group,** announces the formation of a new division, to be known as Engineering Division. Its task will be that of co-ordinating the selling activities of the Birfield Group in conjunction with the existing Automotive, Railway, and Aviation Divisions of Birfield Industries Limited, and at the same time bringing to customers in the general engineering field the benefits of having at their disposal the collective knowledge and combined resources of the whole Birfield Group of manufacturing companies, numbering more than twenty in all.

The Electric Cable Makers' Federation, of Dickens House, 15 Took's Court, London, E.C.4, held its inaugural meeting on January 7, 1958. The Federation, whose initial membership comprises about forty British cablemakers, i.e., almost the whole of the industry, has come into being through a strong and widespread desire on the part of cablemakers to establish a body to act as a forum at which problems of the industry and matters of common interest can be discussed on the widest basis. The Federation will not be concerned in any way with price fixing or any other related activities, nor will it replace the existing Cable Makers' Association, Independent Cable Makers' Association, and other similar trade associations.

Mr. F. Waine, J.P., director of British Insulated Callender's Cables Ltd., and Mr. S. Geipel, chairman of William Geipel Ltd., were elected president and vice-president respectively. The first meeting was necessarily devoted to constitutional matters, but it is expected that the work envisaged will be quickly commenced through its elected committees, to the general advancement of the British cablemaking industry.

Sanders & Forster Ltd., of London, one of the **Chamberlain Group** of companies, are establishing a Caribbean office at 31 Charlotte Street, Port of Spain, Trinidad. The new office will work in close association with Lee Lum Ltd., the company's main Trinidad agents, and will concentrate on developing the sales of their range of standard buildings and specially made structures throughout the entire Caribbean area, including the Eastern seaboard of the U.S.A. and the Northern countries in South America.

Drummond-Asquith (Sales) Limited, of London, W.C.2, announce that they have secured the sole agency and engineering representation of **Ruhrstahl, A.G.,** of Henrichshutte, Hattingen-Ruhr. Specialist engineers will be available for consultation in the main industrial centres, and a new division, to be known as the Ruhrstahl Division, will operate from the company's London headquarters.

CONTRACTS

Orders for rolling-mill equipment to the value of about £4 million have been placed with **Davy and United Engineering Company Ltd.,** of Sheffield, by **South Durham Steel & Iron Co. Ltd.,** as part of their newly announced expansion programme to increase plate production. The plant includes two 150-in. wide 4-high rolling mills, each mill being driven by twin 4500-hp motors, giving rolling speeds up to 1020 fpm. These mills will be capable of producing high-quality steel plate up to 136-in. finished width, as used by the shipbuilding and engineering industries, and output will reach 1000 tons per eight-hour shift. The contract includes a wide range of ancillary equipment.

In addition, Davy-United will build a hydraulic hot slab shear with a power of 2750 tons, capable of cutting slabs of hot steel up to 18 in. thick and 18 tons in weight. Davy-United will also engineer and co-ordinate the supply and installation of some 8000 tons of plate-shearing and finishing machinery. To assist overall delivery of the whole plant, this equipment will be manufactured by **Vickers-Armstrongs (Engineers) Ltd.,** at their Elswick Works, Newcastle-on-Tyne, under Davy-United's engineering supervision. An arrangement now exists between these two companies whereby, in suitable cases, available capacity for steelworks plant can be increased in this way.

Materials Handling Equipment (Great Britain) Limited, of London, W.1., announce that they have received from the Indian Government Purchasing Mission a contract for the supply of a number of "Irion" side-operating fork-lift carriers of 3 tons and 5 tons capacity, for use in the Port of Calcutta. Similar equipment is already in use by the Ports of Basrah, Bangkok, Bordeaux, Hamburg, and Singapore, and by the Ports and Harbours Administration of the South African Railways.

Wild-Barfield Electric Furnaces Ltd. are now building a 40-kW high-frequency induction-heating generator for delivery to Russia. This unit, which has been ordered by Machinoimport, Moscow, is a standard generator incorporating the full range output power control and unit-built sub-assemblies. It occupies a floor space of only 51 × 58½ in.

The order also covers a high-temperature furnace, model HTP 5, one of a range of standard Wild-Barfield high-temperature furnaces with normal operating temperatures from 1100°C to 1350°C.

In addition, Wild-Barfield are completing the manufacture of a 25-kW induction-heating generator, together with a number of fixtures, for use in an automobile factory in Yugoslavia.

Crompton Parkinson Ltd. have secured an order from the U.S.A. for six power transformers valued at upwards of $200,000. These transformers are of 8687 kVA each, single-phase for 115-kV service voltage, and are to be

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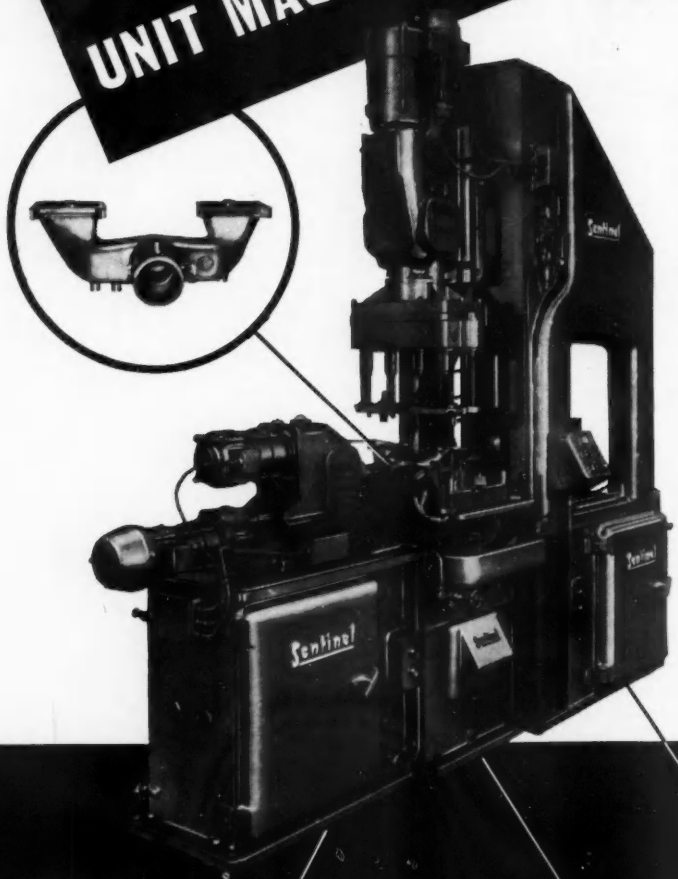
Sentinel UNIT MACHINES

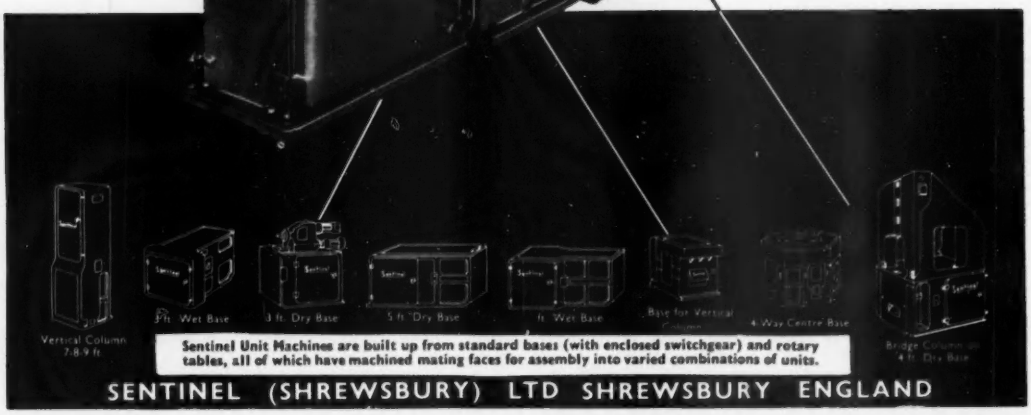
FAST VERSATILE ECONOMICAL



SENTINEL UNIT MACHINES incorporating the Renault-France system electro-mechanical heads.
Built for—Drilling, Boring, Facing and Chamfering. 8 different types of Manifolds (*see inset*). Two manifolds are loaded, pneumatically located and clamped.
Press a button to start—and in less than 30 seconds the machining cycle is completed!

AN EXAMPLE OF FLEXIBILITY

This Unit Machine comprises a
3 ft. Dry Base, and an EMH 10 with Boring, Facing and Chamfering Tools.
3 way Centre Base.
4 ft. Dry Base, and an EMH 10 with Boring, Facing and Chamfering Tools.
Bridge Column, and an EMH 20 with a 12 multi-spindle head.



Sentinel Unit Machines are built up from standard bases (with enclosed switchgear) and rotary tables, all of which have machined mating faces for assembly into varied combinations of units.

SENTINEL (SHREWSBURY) LTD SHREWSBURY ENGLAND

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P4108

employed in the Fremont Canyon Power Project in Wyoming. The Company won this order in the face of strong competition from some twelve other manufacturers, six of them in America and the others in Austria, Italy, and Switzerland, as well as in Britain.

Hayward Tyler, members of the **Platt Brothers** group, have received an order for 48 glandless circulating pumps, to be incorporated in the heat-exchanger circuits of Hinkley Point nuclear power station. These pumps are similar to those on order for Berkeley, Bradwell, and Hunterston nuclear power stations. The approximate value of the contract is £125,000.

Hunt & Mitton Ltd., of Birmingham, announce that they have received a large contract for the supply of high-pressure valves for a new automatic rubber-moulding plant in Russia. The machinery to be used in this new factory is to be put up by a consortium of British companies and the valves will handle steam, high-pressure hot water, and hydraulic fluids on a complicated automatic and manual circuit. The value of the order amounts to approximately £150,000.

ACCIDENTS TO PERSONNEL FROM AUTOMATIC MACHINERY

In the current issue of *Accidents* (Vol. 34, January 1958), issued by the Ministry of Labour and National Service, special attention is given to accidents which have actually occurred in connection with automatic machinery and processes, including electrical equipment, transmission machinery, machine tools, conveyors and elevators, cranes, sand mills, transfer machines, process machinery, fires and explosions, and building and constructional work.

This interesting and timely booklet of 32 pages (H.M. Stationery Office, price 1/3) points out that, for accident prevention, automatic machinery requires that the techniques employed and the assignment of tasks to individuals must be specially considered from the point of view of a safe system of working, the prevention of unexpected starting up of machinery being one of the particular problems.

Based on actual "case-histories" of accidents, the book is graphically (and often grimly) illustrated, and acts as a forceful reminder that industrial accidents account each year for about 700 killed and 180,000 injured, and that every day some 60,000 employees are absent from work as a result of industrial injuries.

COURSE ON CASE STUDIES IN QUALITY CONTROL

The Production Engineering Department of the College of Technology, Birmingham, is offering a course on Case Studies in Quality Control. The course, which commenced on February 4, consists of eight weekly lectures by specialists from various branches of industry, and is designed for personnel whose responsibility is the quality function within their own works and who would therefore already possess some knowledge of the fundamentals of inspection and the control of quality.

The course is planned to include not only quality aspects of engineering products, but also those in relation to food production and clothing manufacture, and the lectures will generally be along the lines of (1) a statement of the nature of the problem and its industrial setting, (2) the method of approach to the problem, and (3) the results obtained and subsequent course of action, each company contributing a case study typical of its operations.

In this way, members of the course will be able to see the application of quality-control methods to industrial problems outside their own particular field, but which may nevertheless cover a certain amount of common ground, thereby assisting them with their own problems.

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are the ONLY units of their kind in the whole world which can take into account the two variable parameters of VISCOSITY & DENSITY and thus MEASURE with the highest degree of accuracy both the VOLUME and the WEIGHT of all liquids, e.g., water, hydrocarbons, acids, and food products (milk, wine, etc.).

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An announcement to those concerned with corrosion of metal surfaces

In 1929 the National Physical Laboratory established that Lanolin was by far the best natural film-forming anti-corrosive available. At that time Croda had been manufacturing Lanolin for four years and was already producing Rust Preventive Oils based on Lanolin.

Since then enormous advances have been made both in the consumption of anti-corrosives and in the variety and complexity of these products. The research and development conducted by Croda has contributed considerably to this progress.

The list of Rust Preventive Oils and Coatings and allied preparations produced by Croda's Organic Finishes Division is so large that we propose only to list headings and groups of products :

Anti-corrosive paints
Anti-freeze solutions
Bituminous solutions
Brake fluids
Corrosion inhibitors
Chrome protectives
Cutting oils
Coolant soluble oils
Carton waxes
Drawing oils
De-watering oils
De-icing fluids
De-greasing fluids
Emulsion degreasers
Fingerprint removers
Greases, special
Grease paints
Lanolin solutions
Metal marking inks
Penetrating oils
Plastic coatings
Paint-tolerant rust preventives
Rust removers
Rust preventives, oily
Rust preventives, grease
Rust preventives, hard film
Sheet-steel coating oils
Soldering flux
Wash primers
Weld marking inks

In addition to this large standard range, the skilled staff of our laboratories is always ready to create new preparations for individual requirements.

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GUIDE TO THE ASSESSMENT OF SURFACE TEXTURE

In continuation of the series of " Codes of Practice ", the Ministry of Defence has issued a new publication entitled " A Guide to the Assessment of Surface Texture " (H.M. Stationery Office, 3s.). The object of this guide, which is based on B.S. 1134: 1950, is to make available to designers, producers, and inspectors the essential information necessary for using up-to-date techniques on surface-finish assessment in an intelligent and practical manner.

IMPROVED ABRASIVE WHEELS

Consequent on the increasing popularity of coated-abrasive techniques in the metal and woodworking industries, an improved and cheaper 3M PG abrasive wheel is announced by the **Minnesota Mining & Manufacturing Co. Ltd.,** of Wigmore Street, London, W.1, who have introduced for the purpose automatic methods of production at their Birmingham factory. Substantial reductions in polishing costs have already been claimed for the PG wheel, but even greater savings are now forecast for the improved version, while prices are down in some cases by as much as 50%.

The wheel consists of numerous die-cut, cloth-backed coated-abrasive segments locked in a hub, and is available in sizes ranging from 6 to 16 in. in diameter, and from 1 to 6 in. in width. The wheel is self-conforming to the shape of any article being polished, and retains this shape throughout its working life, exposing fresh grain as it wears. In this way, it eliminates costly down-time for wheel exchange and re-dressing.

NEW 98% VANADIUM OXIDE

A new 98% vanadium oxide has been added to the extensive list of alloys and metals available from the Alloys Division of **Union Carbide Limited,** 103 Mount Street, London, W.1. The new grade represents a marked improvement over former grades, which average 86–89% vanadium oxide. The reduction of alkali oxide content to not more than 2% is important to furnace operations because of the appreciable elimination of fume hazards caused by these oxides.

The material also offers advantages in reduced sulphur content, silica content, and other contaminants which have a direct bearing on the production of high-quality vanadium steels. 98% vanadium oxide is now available either in a dense fused form suitable for direct addition to an alloy furnace, or in granular form.

IRANIAN OIL PROSPECTS

The future of the Iranian oil industry and the part which Britain can play in developing the country's potential oil resources was the theme of a speech made in London on January 15th, 1958, by Mr. Hector D. Walker (Constructors John Brown), at a luncheon of the Council of British Manufacturers of Petroleum Equipment, at the Dorchester Hotel.

In his opening remarks Mr. Walker gave some indication of the very large sums of money to be spent in Iran in developing its oil resources and, in this respect, made some suggestions with regard to the efforts that should be made to obtain the contracts for such work by U.K. companies. He said that what was required was that British ability had to be sold with goodwill and with an understanding of the other person's point of view. He stressed the importance of not separating the humanities from technology, and that the extent of the goodwill we engendered was a measure of our knowledge of the humanities. He was convinced that, unless we went into a country with this point of view well established in our minds, we would never achieve that ultimate success for our endeavours which was so essential to the well-being of Great Britain.

In describing the future of the oil industry in Iran, Mr. Walker said that there was no doubt that, with her oil and natural resources, fortified by the revenues derived from the sale of oil to the world, we should see an oil and industrial development of increasing magnitude, in which it was up to us to play our part in selling our specialist " know-how " and materials, and in this connection the forthcoming Chemical and Petroleum Engineering Exhibition was of the greatest importance.

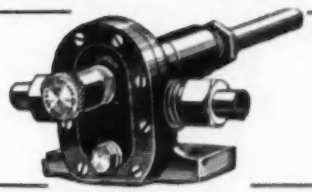
TURBO-ALTERNATOR AT NATIONAL PHYSICAL LABORATORY

A G.E.C. 650-kW geared turbo-alternator set has recently been installed at the National Physical Laboratory, Teddington, as part of an integrated scheme for supplying the heating requirements of the laboratories, and at the same time economically augmenting the electricity authority's supply to the site. The usual method of operating the set is in parallel with the South Eastern Electricity Board's supply, but provision is made for independent working, so that in an emergency the essential services of the laboratory can be maintained.

The turbine, with inlet steam conditions of 210 psi at 540°F, is designed for back-pressure operation, exhaust steam at 40 psi being desuperheated and delivered to calorifiers for central-heating purposes. So as to ensure that the heating requirements can be met under all conditions of electrical load, a by-pass line with a reducing valve and desuperheater is fitted, so that additional steam for space heating can be supplied (via the reducing valve), should the back-pressure of the turbine fall to 1 psi below the normal value.

When the set is synchronized with the grid, the back-pressure is maintained at a constant value by a pressure regulator, the electrical output varying according to the demand for heating steam. It is also possible to run the turbine under speed-governing conditions when isolated

GEAR PUMPS



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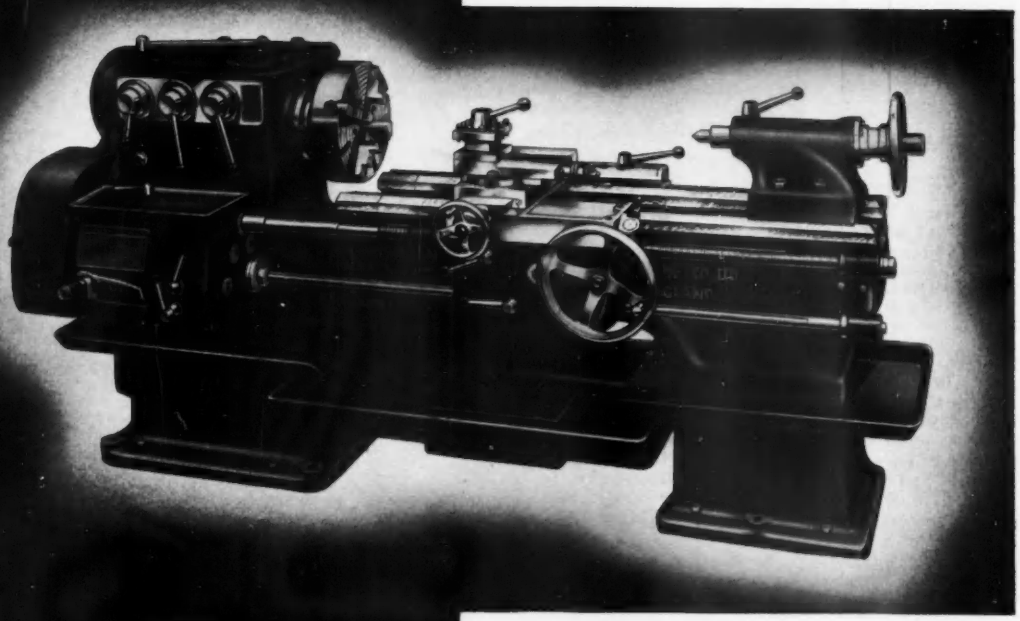
7½" & 8½" CENTRE LATHES



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The most popular of the Crowthorn range, these lathes include in their specification a robust vee type bed, timkenised headstock with large hollow spindle, quick change gearbox and multi position four way toolpost. A hexagon turret is available for either Herbert or Ward tooling equipment.

Please write for detailed literature.

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from the grid, with the back-pressure correctly maintained by high-pressure steam supplied through the reducing valve.

The alternator, driven through 7000/1500 rpm speed-reducing gears, manufactured by the David Brown Corporation Ltd., is rated at 650-kW maximum, 618-kW normal, 3-kV, 3-phase, 50-cps.

HARBOUR RADAR STATION AT SOUTHAMPTON

A Decca Type-32 harbour-radar system has just been put into service at the port of Southampton by the Harbour Board. With a commanding view of Southampton Water and the Solent, the radar aerial is sited on Calshot tower and has become a new and conspicuous landmark at the southern end of Southampton Water. The Decca Type-32 radar will now be providing continuous, up-to-the-minute information on all shipping in Southampton Water, and in the approaches from the east and west Solent. The complete installation at Calshot, which consists of the Decca harbour-surveillance radar and Marconi VHF R/T communication service, provides an advanced port operation and information service, which will be maintained throughout the 24 hours, in any weather, providing all possible information and help to shipping and maintaining a regular, safe flow of traffic.

INTERNATIONAL CONFERENCE ON TRAINING METHODS

The International Conference on Modern Training Methods, organized by the European Productivity Agency, was held at the Auberge des Quatre Tilleuls in Poigny-la-Forêt, near Rambouillet, from January 21 to 24, 1958, and was attended by some sixty delegates from European free-trade unions affiliated to the International Confederation of Free Trade Unions and the International Federation of Christian Trade Unions. All delegates were from trade-union educational and training establishments, and discussions were held on how to give their members (leaders and the rank-and-file) the best possible training to keep abreast of modern developments. The director of the Department of Education of the American trade unions also took part in these discussions.

The particular interest to the European Productivity Agency of such conferences is that the trade-union educational programme is tending nowadays to take on a more technical character, based on modern technological and economic conditions in industry, and with an eye to those that may arise tomorrow. This trend meets two requirements, i.e., that of ensuring that trade-union activities will be guided by a deeper knowledge of all the considerations that apply to the question in hand, and the longer-term requirement of enabling European problems, such as those which will fall within the scope of the new European organizations. These aspects lift the conference out of the realm of trade-union domestic affairs and give it general importance as affecting industrial relations in the Europe of the future.

NEW STANLEY HAMMER FACTORY

Designed to give maximum production within the minimum of space and with an economic labour force, a new hammer factory, incorporating a number of structural innovations, has been opened by **Stanley Works (G.B.) Ltd.**, at Ecclesfield, near Sheffield. Constructed to the most modern standards to accommodate new manufacturing processes, the 30,000-sq ft building features the exclusive use of side-admitted natural lighting, the conventional top-lighting system being avoided to overcome cleaning difficulties tied with the problem of window-obstruction through heavy atmospheric pollution in industrial areas.

The factory, which was officially opened on January 8, comprises a machine shop and forge, together with boiler and air-compressor rooms. The design allows for potential three-directional extensions. Standing on a five-acre site, the road frontage of the factory presents a long stretch of glazing with overhanging eaves, in contrast with a simple brick panel at the end of the office wing.

The machine shop, which measures 210 × 80 × 16 ft, is a bolted steel structure of normal design. It carries a metal deck roofing system on subsidiary purlins, finished with ¾-in. insulation and mineralized felt, laid to fall to a central roof outlet, eliminating the need for external rainwater pipes. The whole main structure is of aluminium. A completely unobstructed clerestory, 4 ft deep, runs around the perimeter of the machine shop. This was contrived by carrying the end walls of the machine shop and the walls of nearby office accommodation and ancillary buildings to a height of only 12 ft. Access to the machine and forge shops is by electrically operated shutter gates; unloading gantries and overhead tracks are used extensively.

The dimensions of the forge shop are 84 × 50 × 20 ft. The building is of normal steel-shed construction with combined asbestos sheeting, giving a clean internal finish and an external appearance which is smoother than the conventional corrugated surface. A continuous ridge ventilator, used with a controlled low-level side-ventilating system, deals with problems arising from excessive heating. Heating is by means of a fully automatic dual-boiler installation, which operates on light fuel oil, in conjunction with a medium-pressure radiant-panel system, using narrow-width radiant panels, mounted vertically above the lower range of ventilators, to give dry conditions for materials storage. Fluorescent lighting is used in the machine shop. Tungsten lighting is installed above the machines and the forge shop. Facilities for interchange and re-arrangement of the fluorescent lighting fittings are introduced by a continuous trunking system.

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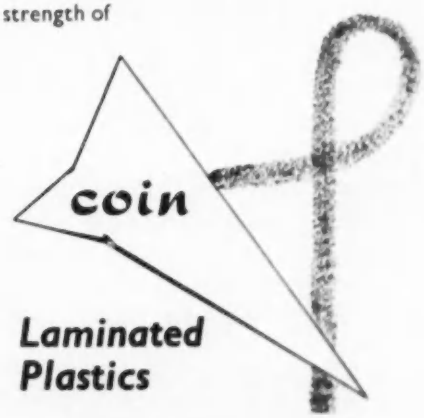

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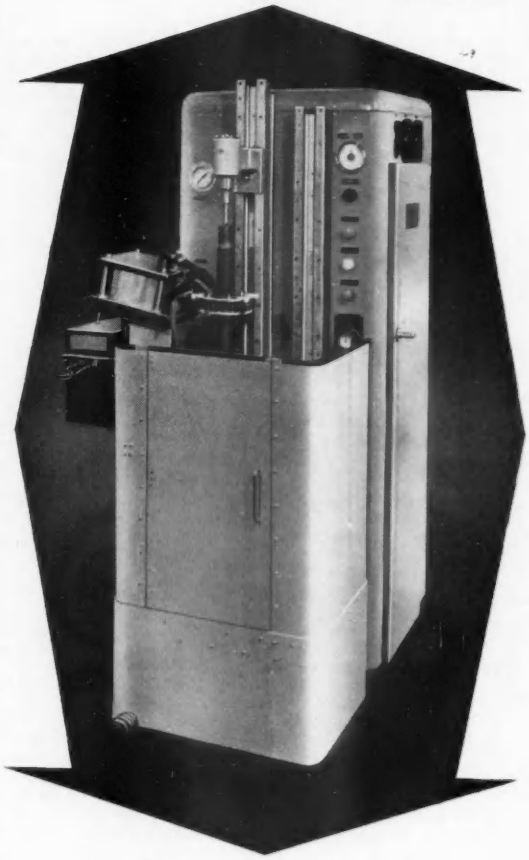

This Radyne unit has been designed to facilitate the handling of parts to be heat treated. Two types are available, 2 ft. & 4 ft. A three-speed, hydraulically driven traverse mechanism enables different depths of hardness to be obtained in one pass. Calibrated controls are provided for easy setting up. Accessories include a quench tank and two timers to control dwell and quench times.

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NEW 10¼-IN. BAR MILL

As part of its general modernization programme, **Sanderson Brothers and Newbould Limited,** of Sheffield, are now bringing into operation a new 10¼-in. double-duo bar mill, made by **The Brightside Foundry & Engineering Company Limited,** and intended to replace two existing mills. A mixed rolling programme of high-speed steels, tool steels, and alloy steels, including steels for bright turning, will be handled. The mill is fitted with roller bearings and will roll to close dimensional tolerances. The double-duo design was chosen because of certain advantages not obtainable with three-high mills, including better size control, elimination of dead passes, and flexibility in operation.

In the new mill, it will be possible to finish in any of the last three stands out of a roll train of five, and the floor is arranged accordingly. The maximum length of bars will be 60 ft and the sizes rolled will be from ⅜ to 1⅜ in. round, and equivalent bar sections and flats up to 3 in. wide. Rolling speed is 300 to 900 fpm. Two existing buildings have been joined to accommodate the mill, and the general arrangement permits a ready transfer of finished material to the heat-treatment and bright-bar departments.

The roll train comprises a reduction-gear drive, with input and output flexible couplings, combined mill pinions and diagonal gear set, five stands of double-duo roll housings, and universal-type mill couplings. Provision is made for the installation of a sixth stand of rolls, if desired. The roll housings are of cast iron, fitted with cast-steel chocks and roller bearings. The top rolls and their chocks are balanced by springs and suspension bolts, adjusted vertically by forged steel screws operated by swivel levers and notched discs.

A supply of river water for cooling the rolls is provided by a pump capable of delivering 400 gpm. Tanks are fitted on each housing, the water level being controlled by a ball-operated valve in each tank. The water is directed onto the rolls by a flexible coolant hose, carrying the scale through a scale pit into a collecting pit which can be cleared, as required. To facilitate roll changing, spare housings are provided, to enable two complete stands of rolls to be prepared with the mill in operation.

For the time being, billets will be heated in a continuous-type pulverized-fuel-fired furnace, which served the previous 10-in. mill. To maintain production, this mill has been kept in operation during the building of the double-duo mill, but, once the double-duo mill is in full operation, the old mill and its steam engine will be dismantled and additional billet furnace capacity added. Live roller gear is provided for the transmission of billets from the furnace to the roughing stand. Hot cogging shears are installed adjacent to the roughing stand, for use when required.

Live roller gear is provided to carry the finished material to the hot saw or shears. Power-operated transfer gear is fitted on the outgoing side of the mill to move bars from the last three stands across the floor to the live roller gear, the transfer gear consisting of seven chain-type skids. Finished bars will be removed by an overhead crane to a despatch section at the end of the mill. Bars for hardening and tempering, normalizing, or annealing will be placed on stillages arranged at the side of the bay in the finishing section, whence they will be picked up by the revolving charging machine in the adjacent heat-treatment department and charged directly into the heat-treatment furnaces.

The mill floor and finishing section will be served by a newly installed three-ton overhead electric travelling crane. An existing overhead crane already serves the despatch section and an 8-in. mill, which, for the time being, will continue to operate in this part of the bay. Mill lighting is by a mixture of tungsten and mercury fluorescent lamps, giving an average illumination of 20 lumens per square foot. Cloakroom accommodation for the workpeople and a new mill office are to be erected.

Classified Advertisements

The rate for all classified advertisements is 9d. per word : in bold print 1s. per word : minimum order 10s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 1st of each month for advertisements to appear in the same month's issue.

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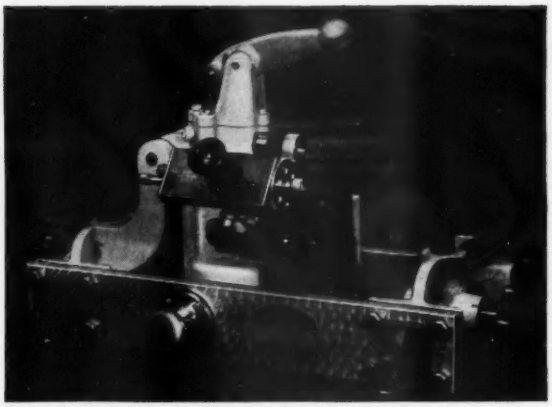

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BOOKS RECEIVED

Gas Turbine Materials. By G. Lucas, Ph.D., B.Sc., A.I.M., and J. F. Pollock, B.Sc., B.Com. 174 pp., 47 illustrations. Publishers : Temple Press Limited, Bowling Green Lane, London. E.C.1. Price : 25/-.

The gas turbine depends for its practical realization as much on metallurgical as on aerodynamic advances, and in this book, which is a survey of high-temperature materials and their applications to the gas turbine, the authors show how material requirements arising from operating conditions in the gas turbine are being met by the current range of alloys.

As Dr. A. T. Bowden says in his Foreword :—" The excellent survey which has been made by the authors of this book on the manufacture, properties, and use of special materials for gas turbines will be read with considerable interest, and will, without doubt, be found most helpful in the use and selection of special materials by designers and users alike."

Indeterminate Structural Analysis. By J. Sterling Kinney. 668 pp., 760 illustrations. Publishers : Addison-Wesley Publishing Company, Inc., Reading, Mass., U.S.A. (U.K. Distributors, Academic Books Ltd., 129 Queensway, London, W.2. Price : 76/-.

Providing an extended introduction to indeterminate structural analysis, this excellent book, intended for students and practising structural engineers or architects, has a coherent, lucid, and interesting presentation. Although the text is introductory, it is not elementary in the usual sense, because of the extended treatment of many of the subjects considered, while the theoretical discussions and solutions of examples presented are exceptionally comprehensive and detailed.

After a brief history of the evolution of structural theory, the theoretical foundation on which the rest of the book is based is developed. Detailed discussions and demonstrations of those methods most frequently used in the analysis of indeterminate structures are included in the book, together with the general method of Maxwell, as modified by Mohr and Müller-Breslau, the method of least work, and an introduction to the column analogy. Other chapters are devoted to discussion of the method of moment distribution, the slope-deflection method for both prismatic and non-prismatic members, influence lines for indeterminate structures, the analysis of arches by either the elastic or the deflection theories, and the basic principles and methods of direct and indirect structural model analysis.

FBI Register of British Manufacturers, 1958. 1138 pages. Published for the Federation of British Industries by Kelly's Directories Limited, 186 Strand, London, W.C.2., and Iliffe & Sons Limited, Dorset House, Stamford Street, London, S.E.1. Price : 42/-.

As always, this new edition (the 30th) of the FBI Register is a comprehensive and accurate guide to a substantial cross-section of British industry, listing the products and services of over 7500 member firms under more than 5400 alphabetical headings.

In addition to the Classified Buyers' guide, there are seven other sections in the Register, giving addresses of companies and firms, and valuable information about trade associations, proprietary names, trademarks, etc. A feature providing a useful reference for buyers not fully conversant with British product terms, is the inclusion of French, German, and Spanish glossaries, which give translations of every product term used in the main buyers' guide, each being numbered for easy reference between the English headings and their translations.

Fluid Pressure Mechanisms. 2nd Edition, 1958. By H. G. Conway, M.A., M.I.Mech.E., F.R.Ae.S. 244 pp., 182 illustrations. Publishers : Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price : 32/6.

Since the first publication of this excellent book in 1949, many developments have taken place in the manufacture and use of light-weight precision industrial hydraulics. As a result, in this second edition, revisions have been made, mainly to repair omissions and to add mechanisms previously overlooked. In addition, many new diagrams have been added, together with new material on slide valves, jacks with force limitations, three-position jacks, special couplings, synchronization systems, and servo-systems.

The book comprehensively covers the mechanism of fluid pressure equipment and systems, i.e., hydraulic, pneumatic, and high-, medium-, and low-pressure compressed-gas systems. It is not concerned with detail design or constructional features, but rather with the essential principles of the various devices discussed, how they work, and how they differ from each other. As such, there can be no doubt that it will be of great value to mechanical engineers in general.

Thermodynamics for Chemical Engineers. 2nd Edition, 1957. By Harold C. Weber and Herman P. Meissner. 516 pp., 154 illustrations. Publishers : John Wiley & Sons, Inc., New York, and Chapman & Hall, Ltd., 37 Essex Street, London, W.C.2. Price : 68/-.

Covering engineering thermodynamics and including an extensive discussion of thermodynamic efficiency, this authoritative book approaches the subject of thermodynamics from the viewpoint of both the engineer and the chemist, making it possible to translate findings from chemical laboratories into the economical production methods of modern industrial plant.

This new edition includes an expanded treatment of fluid flow, together with descriptive chapters on power cycles, engines, turbines, and refrigerators. In addition, many illustrative examples with solutions are given, together with many new problems, all of which are designed to make readers think, rather than calculate. Moreover, Professors Weber and Meissner stress the use of approximate methods of calculation, when complete data are lacking.

LATEST INDUSTRIAL LITERATURE

1. Mechanical Power-Transmission Catalogue. A new illustrated catalogue of nearly 240 pages should undoubtedly prove of great value to all those interested in the subject of power transmission, providing, as it does, a comprehensive list of products available in this field.

Among other items listed is a wide range of V-belts for virtually every type of application, a similarly comprehensive range of flat beltings, V-belt drives and pulleys, and bushes. In addition, details are included of a variety of mechanical leathers and seals, roller chains and chain sprockets, chain drives, anti-vibration shear- and compression-type mountings, single- and double-reduction speed-reducing gearboxes, plate and centrifugal clutches, variable-speed drives, and rigid and flexible couplings of various types.

2. Engine-Testing Equipment. Basically designed and manufactured to meet the special educational requirements of various technical colleges and engineering training establishments, the engine-testing equipment described in a well-produced 16-page brochure comprises an internal combustion engine, a dynamometer, an indicator, an air tank, and a fuel-consumption meter, all combined in a single unit and conveniently mounted on a common baseplate. With this equipment, it is possible to determine efficiency at variable load, heat balance torque, fuel consumption, etc.

Various types of this standard equipment are illustrated in the brochure, but test units based on special specifications can be designed and manufactured, as required.

3. Introduction to Copper. A new publication of about 50 pages, neatly produced and illustrated, describes in clear and simple language where copper is found, how it is extracted from its ores, how it is fabricated, and the various uses to which it is put, together with reference to the many important copper alloys. By virtue of the concise, yet informative, method of presentation of the subject, there can be no doubt that this book is not only of general interest but should also prove useful as a teaching aid in schools.

4. Chemical-Plant Linings. Based on a combination of extensive research and manufacturing facilities, supported by field experience, a complete service described in a 64-page illustrated manual is intended for the supply and application of heavy-duty rubber and allied linings against corrosion in chemical plants.

In this manual, the present methods, materials, and service are detailed for the assistance of all who seek elimination of the problem of corrosion. However, to ensure that this information is current at all times, the manual is in loose-leaf form, facilitating the insertion of additional data sheets as new materials and services become available.

5. Pneumatic Pit-Tub and Mine-Car Retarder. Specially designed for reducing the speed of fast-moving tubs and mine cars without any manual control, the pneumatic retarder described in an illustrated 4-page leaflet is automatic in operation and is a self-contained unit. The machine is simply bolted down in the track, where required to operate, and is not dependent on any external supply of compressed air.

Tubs or cars can be allowed to run into the retarder either singly or in numbers, but they will be released one at a time only at the predetermined speed for which the retarder is set. The adjustment for any particular case can be effected in a few moments.

6. Hydraulic Remote-Control Units. Designed to meet the many requirements for simple, but efficient, manually operated remote-control gear, the hydraulic units described in an illustrated 2-page leaflet have a positive two-way action, with power opening and power closing. Both the master and slave units are easy to install and are rust-proof, vibration-proof, permanently self-lubricated, and temperature-corrected. In addition, the slave unit is quite independent of the master unit, and all working parts are totally enclosed and require no maintenance, while the connecting fluid lines may be bent to follow any desired course. Moreover, there is a positive locking action throughout the operating radius and the system is leak-proof.

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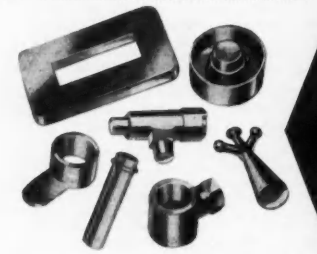

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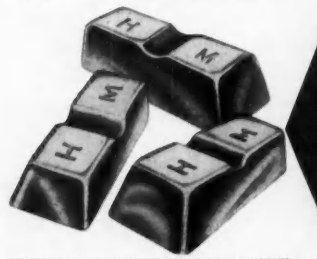

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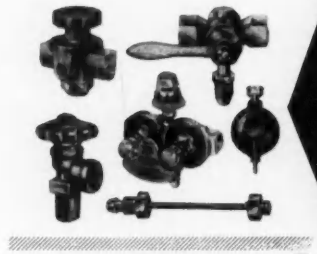

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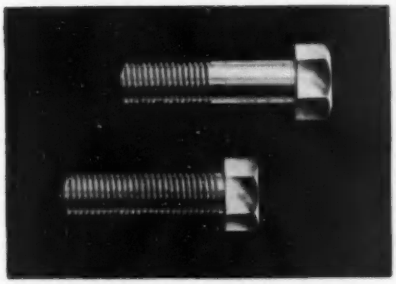

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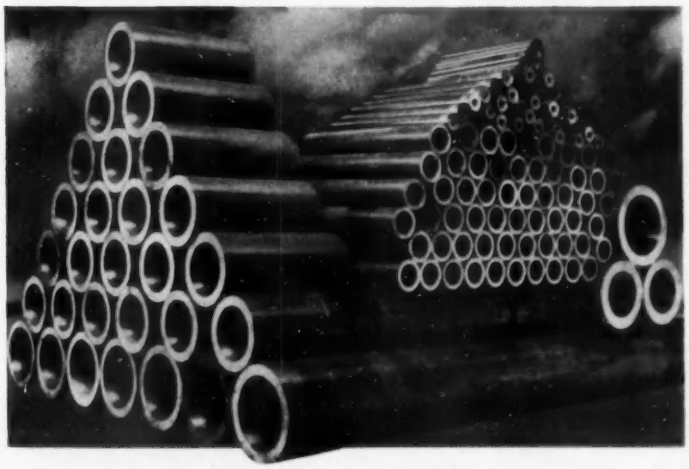

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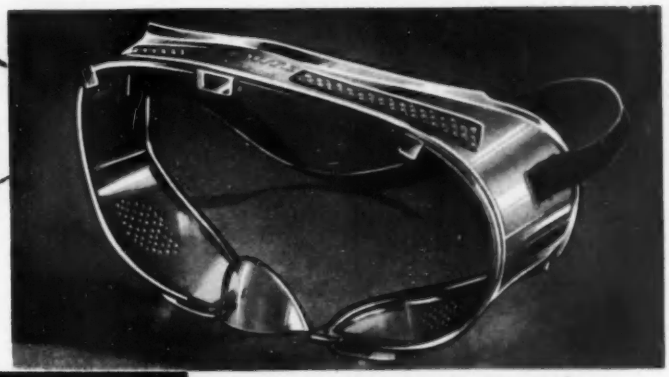

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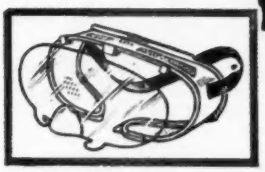

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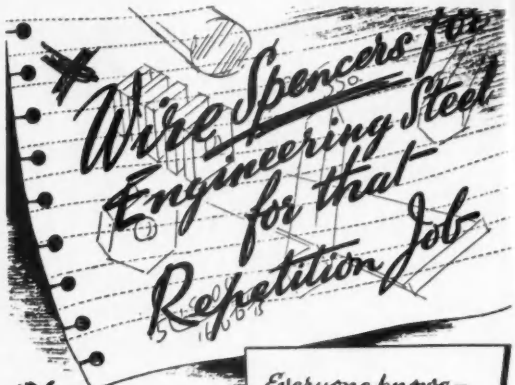

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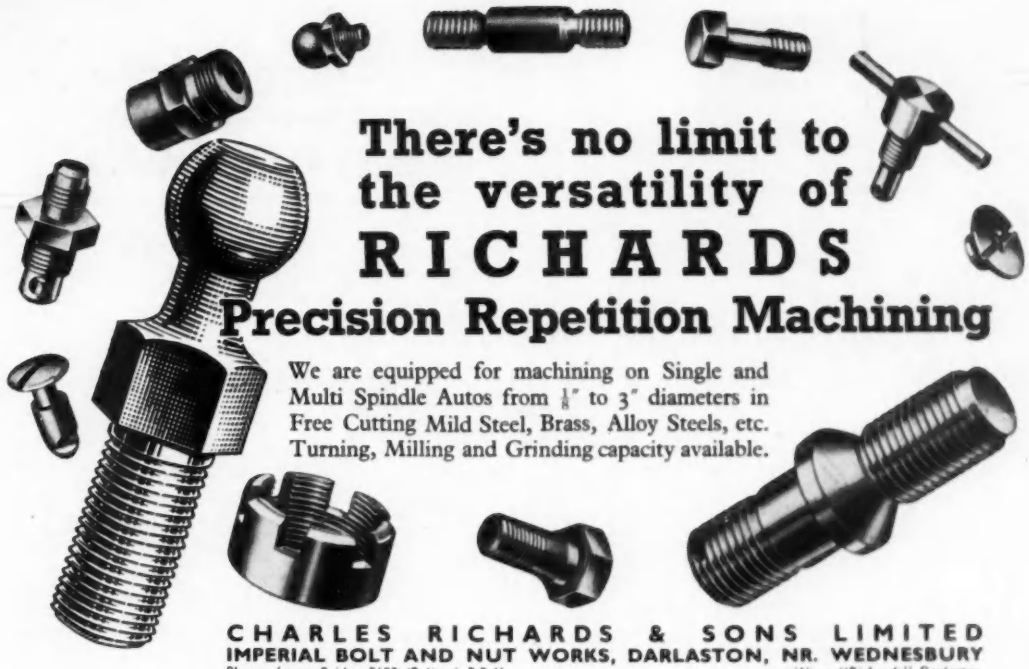

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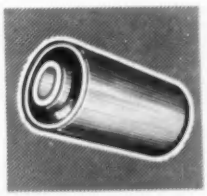

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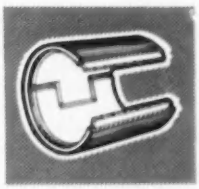

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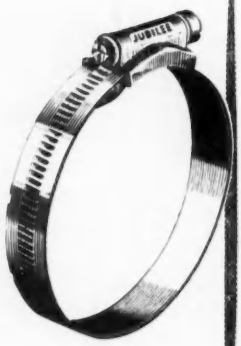

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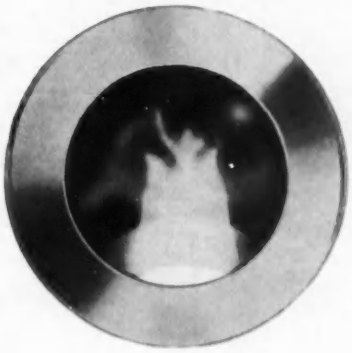

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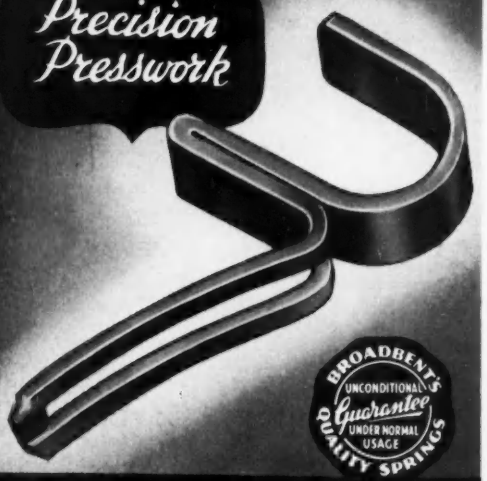

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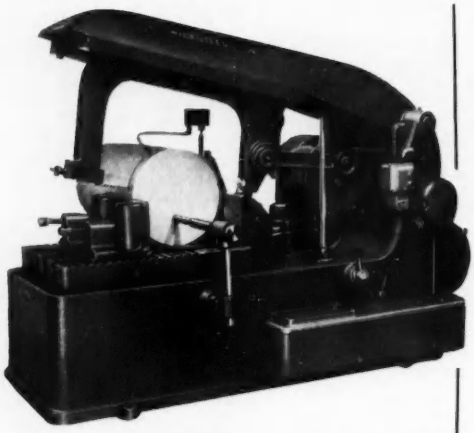

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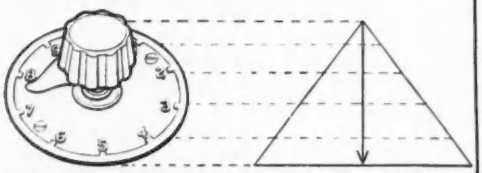

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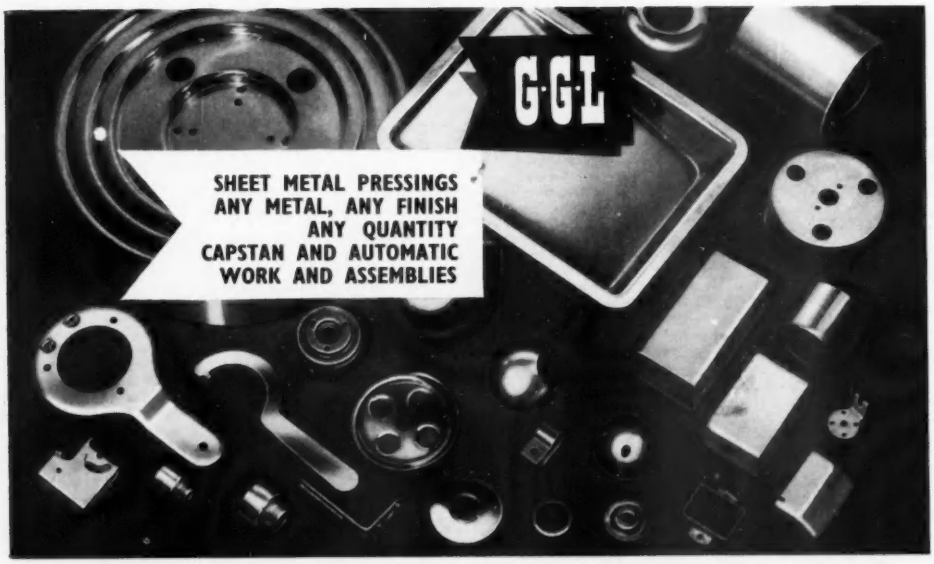

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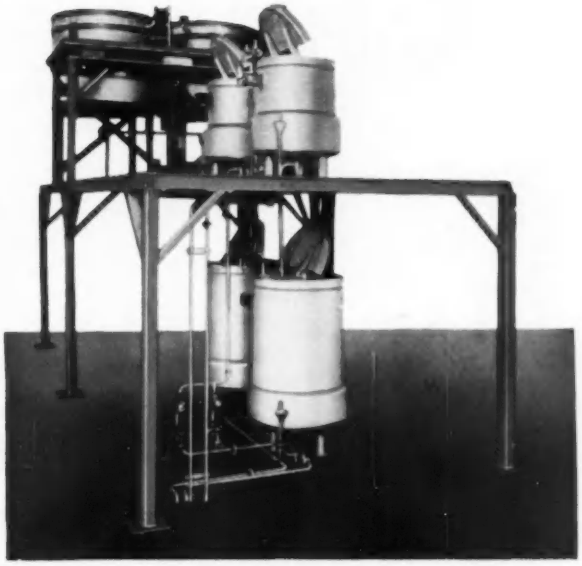

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